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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

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October 2018

Kenya Miniwind

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ISBN: 978-87-93458-33-8

This report is issued by the Kenya Miniwind project funded by the Ministry of Foreign Affairs of Denmark through the Danida Market Development Partnerships. The project aims to explore and develop the market for a partly locally produced kW wind turbine to be integrated into a PV mini-grid for rural electrification in order to reduce the cost of electricity and support local value creation.

The long-term objectives of the project are accordingly to contribute to poverty reduction, stimulate economic growth and increase the supply of sustainable energy. The short- to medium-term objective is to explore the market potential and learn more about how to design solutions and business models that are suitable for rural electrification. The project will therefore conduct a market study, engage in dialogue with local communities and authorities, and demonstrate the technical, social and economic feasibility of integrating a kW wind turbine into a smart solar-powered mini-grid in Kenya. The project will also describe the assembly and production of a key component of the demonstration wind turbine. Finally, the project will work to improve the mini-grid developer sector in both Kenya and the wider region. The aim is that the knowledge generated through these activities will help develop the concept into a viable business model for the private companies involved, thus paving the way for the large-scale deployment of rural wind.

The project is a partnership between SustainableEnergy, Vestas Wind Systems A/S, the Technical University of Denmark, the Kenya Climate Innovation Center and the Rural Electrification Authority.

Ministry of Foreign Affairs of Denmark
DANIDA | International Development Cooperation

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Abbreviations

AFD	Agence Française de Développement
AH	Ampere Hour
CAPEX	Capital Expenditures
DANIDA	Denmark's Development Cooperation
DFID	UK Department for International Development
EMCA	Environmental Management and Coordination Act
ERC	Energy Regulatory Commission
ESIA	Environmental and Social Impact Assessment
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GoK	Government of Kenya
KCIC	Kenya Climate Innovation Center
KEMP	Kenya Electricity Modernization Project
KEREA	Kenya Renewable Energy Association
KfW	German Bank for Development
KNES	Kenya National Electrification Strategy
K-OSAP	Kenya Off-Grid Solar Access Project
KPLC	Kenya Power & Lighting Company
kW	Kilowatt
LCOE	Levelized Cost of Electricity
MoE	Ministry of Energy
MW	Megawatt
NEMA	National Environmental Management Authority
NERA	National Electrification and Renewable Energy Authority
NGO	Non-Governmental Organisation
OPEX	Operating Expenses

PPP	Public–Private Partnership
PV	Photovoltaic
REA	Rural Electrification Authority
REMP	Rural Electrification Master Plan
SREP	Scaling-up Renewable Energy Program
UN	United Nations

1. Introduction

The world is currently witnessing a large-scale roll-out of new renewable energy capacity that is contributing to growth and prosperity while also reducing the environmental impact of power generation. Recent years have seen a number of projects with record low prices for utility-scale wind and solar projects across both developed and developing countries. This trend is expected to continue over the coming years, thereby making these renewable energy sources ever more cost-competitive with conventional energy sources in various markets.

However, we still face the challenge of providing power to the 1.1 billion people currently living without electricity (IEA, 2017). The vast majority of this group live in Sub-Saharan Africa and India, with current projections indicating that by 2030 there will still be 700 million people without access to electricity, 90% of them residing in Sub-Saharan Africa (IEA, 2017). These groups typically live in scattered settlements in rural areas and have relatively low levels of income and consumption. This makes the conventional approach to supplying power inappropriate here, since extending the national grid is not economically feasible, given the distance from the grid and the consumption profile of the target consumers.

Instead, the focus has centred on mini-grids as a viable solution for providing these communities with access to energy. Mini-grids of various sizes can connect houses and villages through a grid that is supplied by energy generated on a small scale and on site. Mini-grids have traditionally relied on diesel generators, but more recently solar PV systems that store energy in batteries have been successfully implemented and are currently seen as the least cost option in Kenya.

This project aims to investigate the potential for integrating modern, small-scale wind turbines into solar-powered mini-grids as a way of further reducing the price of electricity in mini-grids. The price of the electricity produced from wind turbines ultimately depends on the wind resources that are available locally and the investment and running costs for the turbine. However, solar and wind energies complement each other because of the different production profiles of the two energy sources over the course of the day. Thus, the value of the wind energy produced can be much higher when the sun is not shining. By demonstrating that small-scale wind turbines can be effectively integrated into solar-powered mini-grids, this project will help develop the market for solutions to the goal of providing electricity that rural residents in developing countries can afford. In turn, providing access to sufficient and reliable electricity will help sustain the productive and income-generating activities of local communities in order to spur growth, create jobs and alleviate poverty in the rural areas of developing countries.

1.1 Market Segmentation

Wind-turbine manufacturers consider several dimensions when they segment the markets for wind turbines:

- Country-level segmentation of markets
- Pad versus MW constraint markets
- Wind-class segmentation

First, the country-level segmentation looks at legislation and how it is defined nationally, as there may be large differences in terms of grid requirements, noise requirements and bird and wildlife preservation that can affect product development and define the License to Operate in and Enter (LtOE) a given market. Subsequently, a regional segmentation is conducted to account for potential regional differences in legislation within a country.

Second, it is important to understand the limits that different countries have set to the maximum size of large wind-power plants. This is an indicator of whether it is the maximum generating capacity per turbine that is important or the maximizing of the wind-power plant's capacity, based on a given capacity constraint per site.

Third, for each regional or national segmentation, it is vital to have a benchmark understanding of the wind conditions. In the wind industry, most profit will be earned from the highest wind classes, since a high wind-class turbine will generate a higher annual yield than a turbine tailored for a lower wind class.

The above segmentation is not fully applicable to small kW turbines, but in order to remain within this framework, in this report we have used it as a guide in assessing market segmentation.

Country-level segmentation of markets

The project has a regional outlook, and market studies similar to the present one have been published for Tanzania and Uganda. The Kenya Miniwind project has a main focus on Kenya because Kenya has a large number of mini-grids already operational, planned or under development. Kenya also has experience with both small- and large-scale wind power, as well as large areas with reasonable wind conditions. It also has an important industrial base and a policy favourable to industrial development. As the production of wind turbines in Kenya would need a regional market to be beneficial, a study of the market for small wind turbines has also been carried out in Tanzania and Uganda.

Pad versus MW constraint markets

This parameter is not directly implementable here, but the size of the turbine to be demonstrated will be decided on the basis of an analysis of the market for different sizes of wind turbines in Kenya and neighbouring countries.

Small wind turbines (10-100 kW) can be connected to the main-grid or to mini-grids. There could be a market for small grid-connected turbines in areas with good wind conditions, but the potential market for them has not been assessed in this report. Any such market will depend strongly on the conditions for net-metering, non-bureaucratic power-purchasing agreements and the interests of small investors living close to the potential sites for the turbines.

At present, the project's partners are convinced that the market for mini-grids is more viable because mini-grid investors are obliged to invest in production capacity in respect of new or existing grids when demand increases. This means that, if the levelized cost of electricity (LCOE) in the case of wind-produced electricity is competitive with PV-produced electricity in a system using batteries, the mini-grid investor can make the choice to include wind energy in the system. Furthermore, the real value of adding wind may be that additional generating capacity can be added to a system without going to the expense of adding the additional storage capacity necessary if just the solar PV capacity is expanded alone.

The market study has identified all existing and planned mini-grids in Tanzania, including the size of electricity-producing systems, such as PV, diesel, etc., with the objective of providing input into the decision regarding what size of wind turbine to develop in the project.

Wind resource categories
To provide information on this essential parameter, this study divides the planned and existing mini-grids into wind resource categories based on geospatial information regarding the mini-grid locations and on data for annual average wind speeds at 20 m above ground level from the Global Wind Atlas. The sites are divided into 0.5 m/s intervals for wind speeds above 4 m/s.

1.2 Composition of the Report

This report has been produced in collaboration with Kenyan and Danish partners in the project and has benefitted from the various sources of knowledge available to the partners. The first section provides an overview of the existing and envisaged policy for rural electrification in Kenya. It continues with an overview of existing and planned mini-grids in Kenya. Section four describes the public and private market players, while section five provides information on existing wind turbine importers, manufacturers and installers. Section six then links the position of planned and existing mini-grids to the expected wind resource potential and divides the sites into wind speed intervals of 0.5 m/s. Finally, section seven provides a conclusion to the study.

2 Policy Framework for Rural Electrification

2.1 Existing Policy Framework for Rural Electrification

The national development objectives of the Government of Kenya (GoK) include accelerated economic growth, increased productivity in all sectors, equitable distribution of national income, poverty alleviation through improved access to basic needs, enhanced agricultural production, industrialization, accelerated employment creation and an improved rural–urban balance. The extent to which these objectives can be realized in a sustainable manner is dependent on the degree and economic efficiency with which critical factors of production are harnessed to produce the desired results. The provision of quality energy services in a sustainable, cost-effective and affordable manner to all sectors of the economy, ranging from manufacturing, services, mining and agriculture to households, is the key to the realization of the Government's objectives. To meet the country's energy challenge, it must put its available resources and talents to good use.

GoK established a Rural Electrification Programme in 1973 in order to be able to subsidize electricity supply in the rural areas. This reflected a realization that electricity is an important input to the socio-economic development of the country and hence that there was need to increase accessibility to all parts of the country as a means of spurring economic and social development. During the same year, GoK entered into an agreement with the then East African Power and Lighting Company, now the Kenya Power & Lighting Company (KPLC). Under the agreement, KPLC was appointed as a contractor for the planning, implementation, operation and maintenance of rural electrification projects under the programme. Through the Ministry of Energy (formerly the Ministry of Energy and Petroleum) the GoK took responsibility for sourcing the funding of the programme and coordinating its implementation. By 2002, the programme had achieved little coverage despite having been in place for more than thirty years, and only about 4% of the country's rural population had an electricity supply in their homes. Due to the low level of connectivity, and through the Economic Recovery Strategy of 2003 and Sessional Paper No. 4 of 2004, GoK undertook to create a special purpose agency to enhance rural electrification in the country. A Rural Electrification Authority (REA) was eventually created in 2006 through the Energy Act of 2006, becoming operational in 2007.

2.1.1 Rural Electrification Strategy

REA was created under section 66 of the Energy Act of 2006 as a body corporate with the principal mandate of extending the electricity supply to rural areas, managing the rural electrification fund, mobilizing the necessary resources for rural electrification and promoting the development and use of renewable energy (Energy Act, 2006). REA has a mandate to achieve universal access to electricity for all Kenyans in rural areas. Electricity is a key component of achieving socio-economic development in the country. The rural electrification strategy is intended to contribute to the aim set out in Vision 2030 of transforming Kenya into a newly industrialized, middle-income country providing a high quality of life to all its citizens in a clean and secure environment. The focus of the strategy is bettering the lives of Kenyans.

REA's first Strategic Plan (2008/09 -2012/13) corresponded to the first medium-term plan of GoK's development strategy, Vision 2030. REA's goal during this period was to connect 22% of all main public facilities, i.e. secondary schools, trading centres and health centres, by June 2013. The primary mode of electrification was through grid extension, with distribution lines being handed over to KPLC for O&M after project completion. This target was met, and already by December 2012 REA estimated a 26% connectivity rate for the three public facilities. However, although public facilities were connected, the surrounding households were left unconnected, which kept general rural electrification rates low during this period. During the subsequent financial years (2013/14, 2014/15 and 2015/16), REA's focus was on the electrification of primary schools to support GoK's Digital Literacy Programme. While the current strategic plan (2016/17-2020/21) is geared towards electrification of the remaining public facilities and households, there is more focus on renewable energy technologies as a source of electricity and of the diversification of modes of electrification to achieve decentralized production and distribution through mini-grids. The strategic objectives to be achieved under the current rural electrification strategic plan are to develop and promote renewable energy sources, increase electricity connectivity, establish strategic partnerships with stakeholders, strengthen institutional capacity development and achieve financial sustainability. The previous budgetary provision of renewable energy was less than 1%, but with the proposed activities, this is expected to increase to at least 50% of the total budget (REA Strategic Plan 2016/2017 – 2020/2021).

The target under the current strategic plan (2016/17-2020/21) is to electrify all the remaining public facilities and the domestic households in their vicinity by June 2018, concentrating thereafter on the remaining domestic households with the goal of reaching GoK's target of universal connectivity by 2020. While rural electrification rates have increased rapidly over the past few years thanks to large, internationally supported electrification projects, reaching connectivity rates of 78% in urban areas and 60% in rural areas, 17 million people still remain to be connected (IEA 2017).

Some of the activities it is proposed to implement under the current rural electrification strategic plan include:

1. Development of a national renewable-energy master plan to outline the vast renewable energy resources in the country for ease of implementation
2. Development and promotion of renewable energy-generating systems through renewable energy (solar and wind) mini-grids
3. Promotion of partnerships in the implementation of renewable energy technologies
4. Raising awareness of carbon trading in the country
5. Promotion of the development of appropriate renewable energy technologies
6. Supporting the establishment of renewable energy technology demonstration centres in the country.
7. Promotion of environmental conservation in the implementation of renewable energy projects

8. Adoption and adaptation of technology for the utilization of municipal waste to generate energy.

2.1.2 Existing Policy Framework for Mini-Grids

In 2003, GoK embarked on an ambitious sector-development plan and institutional reform, particularly in the field of access, rural electrification and promotion of the use of renewable energy. This program has led to the rapid expansion of grid supply to rural areas, the introduction of renewable energy in various mini-grids and the supply of electricity to public institutions. The Rural Electrification Master Plan update study (REMP) was carried out in 2009 in order to update the national rural electrification strategy for the period 2008-2018. The study identified a total of 33 new sites to be established as off-grid power stations. Rural electrification projects are mainly undertaken by REA, though some works are carried out by Kenya Power, which also connects customers and operates and maintains the national grid. The objective of the rural electrification program, which is financed by the government, is to provide electricity in areas that are far from the national grid and where electricity supply projects are not commercially viable, with a view to improving the social and economic lives of Kenyans in those areas. In accordance with the current policy, REA develops some of the public mini-grids and hands them over to Kenya Power for operation and maintenance, while others are developed by Kenya Power.

2.2 Planned Changes

Among other things, the Constitution provides for a two-level government system (national and county governments) and a sharing of functions that were hitherto the responsibility of the national government. Under the Fourth Schedule of the Constitution, County Governments are responsible for the planning and development of electricity reticulation in respective counties, while the national government is responsible for energy policy relating to electricity reticulation. Rural electrification work is therefore a shared function between the two levels of government. This presents an opportunity for REA to partner with counties to enhance socio-economic development. Section 6 (3) of the County Government Act 2012 provides that a national state organ can co-operate with a county government in the delivery of services by the national state organ in the respective county. REA states that it will continue to align itself with the new constitution and develop a cooperation framework for working with the counties. The county governments will play a role in planning the expansion of rural electrification in their counties either through power-line extensions, mini-grids or solar home systems. In Narok, for example, a solar mini-grid developed by GIZ at Talek was handed over to the county government for operation, who in turn contracted PowerGen to operate and maintain it. The county government will own the power assets that it develops, while the assets handed over for operation and maintenance (e.g. the grid part) will remain the property of the central government in the form of REA.

In compliance with the provisions of the Constitution of Kenya 2010, the Ministry of Energy has drawn up a new Energy Policy and Bill which proposes to enhance REA's mandate in the promotion and development of renewable energy. The documents were tabled in Parliament in April 2015 and are awaiting consideration and approval in the House.

According to the Scaling up Renewable Energy Program (SREP) 2013, the GoK will continue to fund the development of a distribution network through REA, privatize GoK owned mini-grids within the framework of the Privatization Act, and, where commercially viable, progressively connect off-grid systems to the national grid. Where the GoK determines that the supply of energy in an area is necessary, but upon assessment it is determined to be uneconomic or commercially inexpedient to provide for the necessary reticulation by any licensee, the Cabinet Secretary or Governor may undertake the provision of any such works or provide the funds necessary for their development. In the effort to provide affordable energy services to all, GoK will support the development and use of modern and efficient emerging technologies. The newly created counties will have some role in the management of electricity within their borders, particularly in the planning and development of electricity reticulation. The new Energy Act opens up opportunities for regional distributors and allows wheeling charges. It also allows the private sector to set up and operate mini-grids. Reflecting the increasing importance being placed on renewables, as well as the progressive delegation of the implementation of rural electrification to the county governments, GoK proposes to replace REA with the National Electrification and Renewable Energy Authority (NERA), which will have a broader mandate (SREP Report, 2013, MoE).

In 2015, GoK and the World Bank signed a five-year, $461 million loan agreement to implement the Kenya Electricity Modernization Project (KEMP). The objectives of this agreement include increasing access to electricity, improving the reliability of service and strengthening KPLC’s financial position.

The Kenya National Electrification Strategy (KNES) project is financed through KEMP and is managed directly by MoE as the KEMP implementing agency. A contract to develop KNES was awarded to NRECA International in April 2016, and a first draft of the Kenya National Electrification Strategy was released to government in January 2017 (NRECA 2017). The strategy has not yet been published.

2.3 Licensing Process

Electricity

Under Article 27 of the Energy Act 2006, a distribution and generation permit is required for mini-grid businesses with capacity below 3 MW, whereas a licence is required for the generation, transmission and distribution of electrical energy exceeding 3 MW. For more details, see Textbox 1 below. Article 28 requires a notice to be given to Local Authority (County Government) for such projects. In granting the permit, among other things the regulator will check, the tariff to be charged and safety and health of the users of the service. Once the regulator issues a distribution license or permit to one firm, then other firms (including the utility and REA) cannot compete in the same area in the same business. All licensed operators are listed on the ERC website in accordance with Article 40 of the Energy Act 2006.

A study carried out by the ECA Consulting Company in 2014 noted that the electricity generation and distribution licensing procedures were designed for large power projects and were inappropriate for mini-grids (ECA, 2014). It further noted that the current permitting procedures were lengthy and had high transaction costs, as a result of which a number of private mini-grids were operating without permits. It was reported that there is no programmatic approach for firms interested in developing multiple sites, nor any provisions for connecting mini-grids when extensions to the national grid reach the site. It was recommended that light-handed regulation for mini-grids was needed. The study further recommended technical support and capacity-building for county governments covering technical aspects, administration and financial management for the future development of mini-grids. Streamlined regulatory procedures also need to be developed (ibid.).

For small private-sector mini-grids with solar and wind under 100kWp, a generation and distribution permit will be required. To date, three private mini-grid operators (Powerhive, Talek Power Company and Renewvia Energy) have obtained permits to produce and sell electricity to consumers. Other mini-grid operators in the country are operating on pilot status with the ERC.

Environment

Article 58(1) of the Environmental Management and Coordination Act 1999 (EMCA) requires an environmental and social impact assessment (ESIA) to be carried out on all projects at the cost of the proposer and submitted to the National Environmental Management Authority (NEMA) for approval. The ESIA is to be carried out by firms authorized by NEMA, which will issue an ESIA license for each project. Article 68(2) of EMCA requires the owners of the premises or the operator of a project that has been issued with an ESIA license to make annual reports to NEMA describing how far the project conforms in its operation to the statements made in the ESIA report, while Article 68(3) requires the owner of the project to submit environmental audit reports on the project annually.

Business Trading License

A business trading license will be issued by the respective county government where the mini-grid business is to be carried on.

TEXT BOX 1: Excerpt from the Energy Act, 2006

An application for a license or permit, (including an application for amendment, transfer or renewal), shall be made to the ERC in the form and manner prescribed by regulations made by the Minister under this Act. Before making any application for a license, the intending applicant shall give fifteen days' notice, by public advertisement, in at least two national and one regional newspaper of wide circulation and within the time specified for its publication of the intended application. In addition to the notice required above, the intending applicant shall serve a notice in writing with the particulars of the application on every local authority in the area or proposed area of supply and in any other area concerned in the application, but, where the intending applicant is a local authority and the application to be made relates to an area in the jurisdiction of the intending applicant, the provision as to notice to the local authority shall not apply. Every notice as provided above shall state that any person or body of persons desirous of making any representation on or objection to the application or to the grant of the licence shall do so by letter addressed to the Commission and marked on the outside of the cover enclosing it "Electric Power Licence Objection", on or before the expiration of thirty days from the date of the application as stated in the notice and that a copy of such representation or objection shall be forwarded to the applicant. The Commission shall, within fifteen days after receipt of the application, inform the applicant in writing whether the application is complete. The Commission may hear any objections in public, at a time and place of which not less than fifteen days' notice shall be given to the applicant and to every objector and the Commission shall make known its decision regarding any objection within thirty days after the hearing (Article 28).

It further states that ERC shall, in granting or rejecting an application for a license or permit, take into consideration:

(a) The impact of the undertaking on the social, cultural or recreational life of the community;
(b) The need to protect the environment and to conserve the natural resources in accordance with the Environmental Management and Coordination Act of 1999;
(c) Land use or the location of the undertaking;
(d) Economic and financial benefits to the country or area of supply of the undertaking;
(e) The economic and energy policies in place from time to time;
(f) The cost of the undertaking and financing arrangements;
(g) The ability of the applicant to operate in a manner designed to protect the health and safety of users of the service for which the license or permit is required and other members of the public who would be affected by the undertaking;
(h) The technical and financial capacity of the applicant to render the service for which the license or permit is required;
(i) Any representations or objections made under sub-section (4) of section 28;
(j) The proposed tariff offered; and
(k) Any other matter that the Commission may consider likely to have a bearing on the undertaking.

Further the Act states that ERC shall process all applications for a license or permit within ninety days after the Commission confirms to the applicant, in writing, that the application is complete. The Commission shall, where it refuses to grant a license or permit, give the applicant a statement of its reasons for the refusal within thirty days of the refusal. Every license or permit shall be in such form as the Commission may determine and shall, subject to subsection, contain such particulars or conditions where applicable-

1. the provisions for tariffs or charges for the importation, exportation, generation, transmission, distribution and supply of electrical energy to different classes of consumers;
2. the duration of the license or permit;
3. the maximum capacity of supply of the undertaking;
4. the area of supply of the undertaking; and
5. any other matter connected with the carrying on of the undertaking.

All licenses or permits issued by the Commission shall include the following conditions–

(a) a requirement that the licensee or permit holder shall comply with all applicable environmental, health and safety laws;
(b) a stipulation that the licensee or permit holder is subject to liability under tort and the contract laws ; and
(c) a requirement that all necessary fees associated with the license or permit shall be paid on a timely basis

3 Existing and Planned Mini-Grids in Kenya

This section provides an overview of existing and planned public and private mini-grids in Kenya. Further details on the mini-grids described in this section with regard to location, commissioning date, ownership and operator status, and number of connections is available in Annex 1.

3.1 Public Mini-Grids

Kenya Power currently operates twenty-seven mini-grids across the country, the majority of which are situated at the respective county and sub-county headquarters, as shown in Table 1:

Table 1. List of operational public mini-grids

No.	Station	County	Diesel (kW)	Solar (kWp)	Wind (kWp)	Batteries (AH)
1	Marsabit	Marsabit	2900	0	500	0
2	Wajir	Wajir	4200	0	0	0
3	Lodwar	Turkana	3425	60	0	0
4	Mandera	Mandera	3130	330	0	0
5	Habaswein	Wajir	1160	30	50	88,200
6	Merti	Isiolo	250	10	0	0
7	Elwak	Mandera	740	50	0	0
8	Baragoi	Samburu	240	0	0	0
9	Mfangano	Homa Bay	650	10	0	0
10	Lokichoggio	Turkana	1050	0	0	0
11	Eldas	Wajir	184	30	0	72,960
12	Takaba	Mandera	320	50	0	72,000
13	Rhamu	Mandera	520	50	0	0
14	Laisamis	Marsabit	264	80	0	27,816
15	North Horr	Marsabit	184	0	0	0
16	Lokori	Turkana	184	0	0	0
17	Daadab	Garissa	784	0	0	0
18	Faza	Lamu	1370	0	0	0
19	Kiunga	Lamu	260	0	0	0
20	Banissa	Mandera	260	0	0	0
21	Hulugho	Garissa	240	0	0	0
22	Lokiriama	Turkana	800	0	0	0
23	Kamorliban	Mandera	402	0	0	0
24	Kotulo	Wajir	360	0	0	0
25	Kholondile	Wajir	184	0	0	0
26	Kakuma	Turkana	800	0	0	0
27	Biyamadhow	Wajir	50	60	0	78,600

(Source: Eng. Henry Kapsowe, Chief Engineer, Kenya Power, Off-grid Power Stations and Eng. Kihara Mungai, MoE, Wind Energy Data Analysis Programme)

These stations mainly run on diesel, and their customers enjoy similar tariffs as the rest of the country. This is made possible through cross-subsidies such that the generating and operating costs of these projects are spread across all Kenya Power customers, thereby shielding the customers from paying the true cost of power. Ten of the operational mini-grids have been hybridized with solar energy and two with wind energy, as shown in Table 1 above. Three solar-diesel hybrid stations use battery storage, and one diesel-wind hybrid flywheel storage for stabilization. There are plans to expand the existing share of renewable energy, a total of thirteen mini-grids being covered under an upcoming hybridization project (Source: Kenya Power, Eng. Henry Kapsowe). Additional mini-grid sites that are currently being developed by REA and are expected to be commissioned in 2018 are listed in Table 2:

Table 2. REA's mini-grids under construction

No.	Station	County	Diesel (kW)	Solar (kWp)	Wind (kWp)	Batteries (AH)
1	Maikona	Marsabit	700	0	0	0
2	Sangailu	Garissa	50	60	0	78,600
3	Liboi	Garissa	50	60	0	78,600
4	Eldera	Garissa	50	60	0	78,600
5	Garsweino	Garissa	50	60	0	78,600
6	Kiliwehiri	Mandera	50	60	0	78,600
7	Burduras	Mandera	50	60	0	78,600
8	Arabia	Mandera	50	60	0	78,600
9	Gari	Mandera	50	60	0	78,600
10	Shimbir Fatuma	Mandera	50	60	0	78,600
11	Ashbito	Mandera	50	60	0	78,600
12	Ambalo	Marsabit	50	60	0	78,600
13	Balesa	Marsabit	50	60	0	78,600
14	Illaut	Marsabit	50	60	0	78,600
15	Kerio	Turkana	50	60	0	78,600
16	Napelilim	Turkana	50	60	0	78,600
17	Lowarengak	Turkana	50	60	0	78,600
18	Letea	Turkana	50	60	0	78,600
19	Lopeduru	Turkana	50	60	0	78,600
20	Kangangipur	Turkana	50	60	0	78,600
21	Sarman	Wajir	50	60	0	78,600
22	Riba	Wajir	50	60	0	78,600
23	Gurar	Wajir	50	60	0	78,600
24	Basir	Wajir	50	60	0	78,600
25	Hadado	Wajir	50	60	0	78,600
26	Sarif	Wajir	50	60	0	78,600

(Source: Eng. James Muriithi, REA)

The REA strategic plan has identified 629 un-electrified trading centres, 450 of which they plan to electrify through the establishment of renewable energy mini-grids.[1] The

[1] https://www.esi-africa.com/kenya-rural-electrification-authority-to-invest-2-1bn-in-power-network/

balance of the trading centres and other public facilities will be electrified by connecting the existing diesel mini-grids to the national grid.

3.2 Private Mini-Grids

There are several private companies operating private-owned mini-grids in Kenya. The private model is employed in all of them with generation and distribution assets owned by the same company. The tariff charged in all these mini-grids is reflective of cost. The private mini-grids in the country are listed in Table 3:

Table 3. Private mini-grids

Developer	Site	County	PV Capacity (kWp)	Batteries	Status
Powerhive	Kirwa C	Kisii	10	N/A	Operational
	Mtangamano	Kisii	21	N/A	Operational
	Bogeka	Kisii	10	N/A	Operational
	Mokomoni	Kisii	1.5	N/A	Operational
	Nyamondo	Kisii	10.5	N/A	Operational
	Barane	Kisii	47.25	N/A	Operational
GIZ	Talek	Narok	40	108,000	Operational
RVE.SOL	Sindonge	Busia	7	26,040	Operational
Dream EP	Remba	Homa Bay	15	3,000	Disconnected
Dream EP	Ngoswani	N/A	3	300	Operational
PowerGen	Oloilamutia 1	Narok	2.25	440	Operational
	Oloilamutia 2	Narok	2.25	440	Operational
	Naikara	Narok	4.5	400	Operational
	Nkoilale	Narok	1.5	220	Operational
	Olposmoru	Nakuru	6	660	Operational
Access Energy (now SteamaCo)	Sereolipi 1	Samburu	1.5	220	Unknown
	Sereolipi 2	Samburu	1.5	220	Unknown
	Gambela 1	N/A	1.5	220	Unknown
	Gambela 2	N/A	1.5	220	Unknown
	Merille	Marsabit	1.5	N/A	Unknown
Renewvia Energy	Ndeda	Siaya	9.75	1000	Operational
	Ringiti Island	Homa Bay	20.475	2000	Operational

(Source: Nickson Bukachi; ERC, Jackson Mutonga, GIZ; RVE.SOL; Brian Sikuku, Renewvia Energy)

Community-based mini-grids implemented with donor finance are listed in Table 4.

Table 4. Community-based mini-grids

Developer	Site	County	PV Capacity (kWp)	Batteries	Status
Renewable World	Ragwe beach (Kameta and Kanyakongo)	Homa Bay	5	4800	Operational
	Ng'ore Beach	Migpori	1.5	800	Operational
	Mirunda	Homa Bay	3.5	4000	Operational
	Sika, Magetta Island	Siaya	3	3200	Operational
	Kiwa Island	Homa Bay	5	4800	Operational
	Got Kachola Beach	Migori	2	1600	Operational
	Tabla Beach	Homa Bay	1.5	400	Operational
University of Southampton /Energy for Development	Kitonyoni	Makueni	13.5	Yes	Operational
	Oloika	Kajiado	13.5	Yes	Operational
	Shompole	Kajiado	8.4	Yes	Operational
UNIDO	Olosho-Oibor	Ngong	7[2]	Yes	Operational

(Sources: Geoffrey Mburu, Renewable World; (Gollwitzer, 2017), University of Southampton)

Mini-grid sites under development by private developers are listed in Table 5:

Table 5. Private solar mini-grids currently under development

Developer/ Owner	Site	County	Solar Capacity (kWp)	Batteries
Nirav Agencies Limited	Naduat	Turkana	40	Yes
	Lorupe	Turkana	20	Yes
	Kataboi	Turkana	40	Yes
	Longech	Turkana	45	Yes
	Illeret	Marsabit	25	N/A
	Dukana	Marsabit	35	N/A
Strauss Energy Limited	Kangatotha	Turkana	16	Yes
	Katilia	Turkana	40	Yes
	Nakurio	Turkana	25	Yes
Renewvia Energy	Korr	Marsabit	60	Yes
	Ngurunit	Marsabit	27	Yes
	Kiwa	Siaya	11	Yes
	Oyamo	Siaya	10	Yes
	Kalobeyei Town	Turkana	20	Yes
	Kalobeyei Settlement	Turkana	60	Yes
GIZ has taken over from KfW	Kalokol	Turkana	370	N/A
	Ngurunit	Marsabit	180	N/A
	Dukana	Marsabit	140	N/A

(Source: Jackson Mutonga, GIZ; Brian Sikuku, Renewvia and Nickson Bukachi, ERC)

[2] In addition to solar PV, this mini-grid consists of a 3 kW wind turbine with a separate battery bank.

GIZ is co-financing the Turkana sites under the Pro-Solar program. According to information from GIZ, feasibility studies and licence applications are ongoing, but with major delays on the government side.

3.3 Mini-grids as Public and Private Partnerships

The World Bank Kenya Off-grid Solar Access Program (K-OSAP) project is planning to implement solar mini-grids in fourteen under-served counties using Public and Private Partnership (PPP) arrangements. The implementing agencies will be Kenya Power and REA. A total of 121 mini-grid sites are proposed under this program, distributed as shown in Table 6 (further details of 89 of these mini-grids are available in Annex 1).

Table 6. List of K-OSAP sites currently at the planning stage

Territory	Counties	Number of Sites
Northwest	West Pokot and Turkana	26
North	Marsabit, Samburu and Isiolo	29
North East	Mandera and Wajir	32
East	Garissa, Tana River and Lamu	23
Southeast	Kilifi and Kwale	1
South	Taita Taveta and Narok	10
Total		121

4 Public and Private Market Players

4.1 Business Models Used by Operators

The currently existing mini-grids fall under four models, namely the public model, the private concession model, the public private partnership model and the community-based model. A third model of Public and Private Partnership (PPP) is proposed for future mini-grids under the K-OSAP.

1. **Public Model.** This involves the government fully funding the development of the mini-grids. This has been the case with all the existing public off-grids, where REA is in charge of the implementation of projects (construction of generation and distribution infrastructure), handing over to KPLC for operation and maintenance. Under this model, KPLC charges a uniform tariff across the country, as the operational cost is cross-subsidized. This model has contributed greatly to the economic and social development of remote sites such as Mandera, Marsabit, Lodwar, Lamu, Garissa, Wajir etc., as they receive electricity at the same tariff or price as other parts of the country. The mini-grids in Garissa and Lamu expanded so much that they then became economically viable for connection to the national grid.

2. **Private Concessions Model.** In this model a private developer and operator sources all the finance for the development and retains ownership of the assets, supplying electricity and charging for the service at a cost-reflective tariff. The tariff

applicable in this case will always be higher than the national grid tariff as it will be guided by the levelized cost of energy so that all the costs, including the costs of capital, will be covered. This is currently the model used by the existing private mini-grids, which are operating at pilot status with the regulator, as they do not meet the uniform national tariff. If the private developer is to charge similar tariffs to KPLC, then subsidies must be offered. Donor funding is available under the Green Mini-Grid (GMG) Facility, which aims to subsidize the capital costs for private green mini-grids so as to lower the tariff. The tariffs for these mini-grids are still lower than for alternative sources of energy such as individual diesel generators and kerosene.

3. **Public Private Partnership (PPP) Model.** Here the private developer invests in the generation of power (distribution assets will be funded by GoK) and sells power to KPLC as the sole counterparty to its Power Purchasing Agreement (PPA). KPLC will thereafter distribute and supply power to customers at its uniform national tariff, despite having purchased it at a higher cost and incurred additional distribution expenses, including recovery of the capital cost of the distribution assets. A cross-subsidy within the KPLC customer base is applicable to compensate for the losses incurred. Under K-OSAP, the private company will receive a grant for partly funding the electricity-generating assets so as to lower the tariff charged to KPLC. It will also be required to build the distribution network, which will, however, be fully funded by the government, and also to enter into a long-term operation and maintenance contract with KPLC. The customers will be charged by KPLC through prepaid or smart meters. K-OSAP has plans for fourteen counties that are considered to have low electrification rates, and it is expected to accelerate electrification in these counties with a target of achieving universal access to electricity by 2020. The PPP mini-grids under K-OSAP will charge the uniform tariff.

4. **Community-Based Model.** A community, cooperative or municipal utility builds, owns and operates the mini-grid. Most community-based mini-grid development has been carried out on a project-to-project basis supported by NGOs and universities. Recently the UK-based charity Renewable World has implemented a portfolio of projects in Kenya. The practice of licensed electricity cooperatives operating mini-grids has no precedent in Kenya.

5 Public and Private Market Players for Mini-Grids

Below is a list of the players in the mini-grid business:

Development and Operation of Public Mini-grids

1. Ministry of Energy – provides policy guidelines
2. REA – develops and hands over to KPLC for operation and maintenance
3. KPLC – operation and maintenance of all public mini-grids; development of some mini-grids under K-OSAP
4. ERC – handles regulatory issues, including licencing and tariff approvals.

Promotion and Funding of Private Mini-Grids

1. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
2. UK Department for International Development (DfID)
3. World Bank

Existing Private Mini-grid Developers and Operators

1. RVE.SOL. A social enterprise is currently operating one 40kWp solar mini-grid at Sindonge village in Busia County and is planning to develop others in the same area.
2. GIZ. The German federal development corporation developed one 40kWp solar mini-grid at Talek in Narok County, which was handed over to the county government. Operation and maintenance of this mini-grid has been subcontracted. Currently GIZ is promoting the development of solar mini-grids by the private sector.
3. PowerGen has developed and is operating several micro solar mini-grids in Kenya and Tanzania.
4. Powerhive has developed and is operating several solar mini-grids in Kisii County and is planning a major expansion under the Green Mini-Grid (GMG) Facility.
5. DREAM EP Global Energy, Kenya, is part of EP Global Energy and has developed a few mini-grid sites.
6. Renewvia developed and commissioned two mini-grids in 2018 and has several sites under development.
7. SteamaCo (formerly Energy Access) has previously developed mini-grids, but is now primarily a supplier of monitoring and metering solutions.

5.1 Major Donor-Funded Mini-Grid Projects in Kenya

The following are the major donor-funded mini-grid projects in Kenya:

1. GIZ Pro-Solar. Supporting the development of private solar mini-grids in Turkana, Samburu and Marsabit Counties. The project developed a 40kWp solar mini-grid at Talek in Narok, which is currently operational, as an example of a sustainable and viable private-sector solar mini-grid business model. The mini-grid is licensed and charges a cost-reflective tariff. Currently the project is co-funding (up to 40% CAPEX)

the development of new solar mini-grids in Turkana County. Feasibility studies for mini-grid sites in Marsabit County are also going on. There have been major delays in developing the private mini-grids mainly due to uncertainty over GoK's plans and fears that they may interfere with the private mini-grid business.

2. Agence Française de Développement (AFD). Hybridization of thirteen existing government-owned diesel-based mini-grids with solar and wind to reduce fuel costs. The planned sites are listed in Table 7.

Table 7. Planned hybridization of existing public diesel mini-grids

No.	Station Name	County	Existing Diesel Capacity (KW)	Existing Solar Capacity (kWp)	Existing Wind Capacity (kW)	Proposed Additional Solar Capacity (kWp)	Proposed Additional Wind Capacity (kWp)	Proposed Battery Storage (kWh)
1	Mandera	Mandera	3,130	330	0	1,500	0	160
2	Wajir	Wajir	4,200	0	0	1200	300	200
3	Hola	Tana River	800	60	0	1100	0	100
4	Merti	Isiolo	250	10	0	244	0	1,423
5	Habaswein	Wajir	1,160	30	50	1,024	0	5,036
6	Elwak	Mandera	740	50	0	589	0	3,709
7	Baragoi	Samburu	240	0	0	238	0	1,580
8	Mfangano	Homa Bay	650	10	0	183	0	1,354
9	Rhamu	Mandera	520	50	0	210	0	358
10	Eldas	Wajir	184	30	0	234	0	763
11	Takaba	Mandera	320	50	0	235	0	401
12	Lokori	Turkana	184	0	0	399	0	365
13	Hulugho	Garissa	184	0	0	98	0	222

(Source Eng. Henry Kapsowe, Chief Engineer, Off-grid Power Stations, KPLC)

3. Nordic Development Fund (NDF). Hybridization of Lodwar government-owned diesel-based mini-grid with solar energy to reduce fuel costs. Lodwar is in Turkana County, and the planned capacity of the solar plant is 600kWp.
4. DFID – (GMG) Facility. The GMG Facility aims to enhance access to energy in Kenya by encouraging private investment in renewable energy-based mini-grids. The facility provides technical assistance, milestones investment grants and output-based grants in order to facilitate sustainable and scalable business models. The GMG Facility will also prepare businesses for longer term financing by linking them with investment opportunities and financing such as SUNREF, which is a green credit line for companies developed by AFD. AFD is the implementing partner for this facility, and Innovation Energie Développement (IED) is the managing entity in partnership with I-DEV and Practical Action Consulting, being responsible for the implementation of the Facility.
5. World Bank K-OSAP project.
   This project is planning to implement 121 mini-grids under a PPP at a total cost of USD 40 million (see description above).

6 Existing Wind-Turbine Importers, Manufacturers and Installers

6.1 Historical Account of Small-Scale Wind in Kenya

The history of small-scale wind in Kenya started in the 1980s, when mostly donors were engaged in various pilot projects to test the feasibility of small-scale wind energy. However, the success of these projects was rather limited, and no further developments were recorded until the late 1990s. Around this time, established importers of energy systems started expanding their product portfolios by adding small-scale wind turbines. After this followed a period of considerable experimentation and learning within the sector. GoK also gradually placed greater emphasis on the small-scale wind-turbine sector, while universities initiated research, non-profit organizations implemented support programs, and in 2009 Kenya held its first conference for small-scale wind turbines. At the same time, the number of local manufacturers of small-scale wind turbines increased markedly. In general, small-scale wind turbines are manufactured for either power generation or water pumping.

The use of small-scale wind turbines for water pumping is more widespread in Kenya and started as early as 1986. According to records, 300 to 350 windmills were being used to pump water in 2005. Furthermore, various local companies exist supplying small wind turbines for households and small businesses, suggesting that this constitutes another market for small-scale wind. However, the lack of coordinated and official information regarding this market entails suggests that its size must be considered rather limited. Two wind projects that are mentioned by the Ministry of Energy on its website are the St. Patterson Memorial Secondary School in Kaijado (3 kW), which powers classrooms and dormitories, and the North Horr Boys' Secondary School (200 W) in Marsabit, likewise powering classrooms.

In total, while the use of large-scale wind energy in Kenya is gathering pace (particularly with the Lake Turkana wind project), the use of small-scale wind has thus far been rather limited in terms of electrification. Using small-scale wind for water pumping is more common in the country.

6.2 Current Status of Firms in the Sector

The general characterization of the sector for small-scale wind turbines in Kenya is best described as one offering relatively simple designs that are manufactured locally, can be tailored to different local contexts and use a range of locally available materials. As such, these locally manufactured turbines do not require advanced engineering knowledge or skills and are rather the result of a sector relying on informal knowledge networks in which blacksmiths and other local craftsmen tinker with various designs based on the available equipment and materials. The equipment and materials are often acquired through connections in the local environment that are also used as a distribution network.

While the costs of producing and distributing these turbines are low, their performance and quality tend to vary greatly. The lack of experimentation with wind-powered mini-grids means that only limited experience and knowledge have been accumulated within the sector. The turbines manufactured locally typically boast a capacity between 150 W and 3 kW, with roughly 120-150 installed turbines of this range in Kenya (Vanheule, 2012). However, the Kenya Renewable Energy Association (KEREA) mentions on its website that a few local Kenyan companies have recently started manufacturing turbines in the range of 150 W to 6 kW, with fifty having been installed to date.[3] Without further specification regarding what is meant by "recently", it is difficult to assess the actual state of affairs with local manufacturers of wind turbines.

In general, since 2011 local suppliers of wind turbines have moved towards the emerging market for solar-powered mini-grids and the comparatively limited size of the market for wind turbines (AHK, 2013). Two examples from Kenya include a local manufacturer called WinGen, which began the production of small-scale wind turbines in the late 1990s, has since changed its name to PowerGen and is currently focusing its activities on solar-based mini-grids. The other example is Access:Energy, which was set up in 2009 to train local craftsmen in making wind turbines from scrap metal. It later changed its name to SteamaCo and has since developed a smart metering and monitoring system and implemented solar mini-grids in collaboration with PowerGen and investors. Also, around 2010-2011, just when local manufacturers started moving away from the production of turbines, three foreign manufactures started activities in Kenya and have since installed a smaller number of turbines. In addition to the small turbine manufacturers, it is also evident that universities, donors, government agencies and NGOs –are likewise engaging in the production of small-scale turbines to varying degrees in relation to community and pilot projects (Harries, 1997; Bergès, 2009; Ferrer-Martí et al., 2012). According to KEREA, two other local companies are engaged in the manufacturing and installation of wind turbines for water pumping, with 300-350 installations to date.[4]

In general, the performance of imported small-scale wind turbines, which are typically used in existing hybrid mini-grids, is generally better, but also more expensive compared to locally manufactured turbines (Vanheule, 2012). The capacity of imported turbines is around 1-5 kW, and an increasing number of local manufacturers are offering imported turbines from China. Detailed information about Chinese wind turbines installed in Kenya is limited, but it is estimated that around twenty local companies currently offer imported wind turbines (Kamp and Vanheule, 2015). These companies are primarily installers of solar PV systems that complement their energy product portfolio with wind turbines. Two American companies have been highlighted as the preferred partners for local companies importing small-scale wind turbines: Southwest Wind Power and Bergey Wind Power (Vanheule, 2012).

In the following, brief descriptions of some of the local companies that are engaged in either importing, manufacturing or installing small-scale wind turbines in Kenya are provided. The companies have generally been found through an online list of wind energy

[3] http://kerea.org/renewable-sources/wind-energy

[4] http://kerea.org/renewable-sources/wind-energy/

businesses in Kenya.[5] Most of the details presented below are based on information available on companies' websites and have thus not been verified through other sources. Companies presented below are ranked so that those with the most reliable and available information are listed first.

East African Wind Energy Ltd (EAWEL)[6] focuses its activities on renewable energy technologies, including wind in East and Central Africa. It was established by a group of Kenyan businessmen to act as an independent power producer providing renewable energy solutions. It is registered as being active in retail sales, wholesale supply and imports of renewable energy technologies. Regarding wind turbines, it offers customers support in identifying the most suitable wind turbine on the market and assists in the subsequent installation and commissioning of the system. It also provides and installs wind-data logging systems. Previous projects include the installation and commissioning of 42 and 50 meter wind masts at Pwani Oil Ltd and Mombasa Cement Ltd respectively. However, these projects date from 2009, and information on more recent projects is generally absent on their website. The latest news and events on their website date from 2011 and include one project in partnership with a Danish firm, Amplex, to "provide smart grid and energy management solutions to the region".

Kijito Windpower[7] started producing wind turbines for water pumping in Kenya commercially back in 1979, originally supported by the British Department for International Development (DfID). Since then Kijito has designed, manufactured and installed more than five hundred wind turbine water pumps across eastern Africa, three quarters of them in Kenya. According to its website, it is currently looking into the possibility of expanding its portfolio of rural energy solutions by also manufacturing wind turbines for power generation. Its current product portfolio includes five different types of turbine for water pumping ranging from 12 to 26 feet in height. The website also mentions the option of hybrid wind and diesel, but without any further information. Among its previous projects, its installation of a 1 kW wind turbine at the Esilanke Primary School in 2007 should be highlighted. The electricity generated from the turbine charges batteries, was made possible with funding from DANIDA and was developed by Danish wind-energy consulting firm KenTec and its Kenyan partner Windgen (now PowerGen). Kijito was responsible for the installation of the turbine. More recent references to projects are absent from their website.

Craftskills East Africa Limited,[8] established in 1999, was the first local manufacturer of small-scale wind turbines for power generation, as well as wind-power water pumps. Its solutions mostly target individual households, communities, schools and other public facilities, as well as business premises such as hotels and lodges. It offers two types of generator, which, depending on the application, can go from 150 W up to 12 kW. It has

[5] http://energy.sourceguides.com/businesses/byGeo/byC/Kenya/byP/wRP/wRP.shtml#31680

[6] http://www.eawel.com/index.html

[7] http://kijitowindpowerkenya.com/index.php

[8] http://www.craftskillseastafrica.com/b-one-default.html

installed more than eighty wind turbines across Kenya, Tanzania, Rwanda, Cameroon and Nigeria.

Winafrique Technologies Limited[9] is an integrated renewable energy resource company with a main emphasis on wind–solar hybrid systems. When it was established in 2001 it became the first dealer focusing exclusively on small-scale wind turbines. The company typically participates in the development of projects together with governments, NGOs and other types of institutions. It has conducted projects in telecommunications, schools lighting and ICT, water desalination, and irrigation for farming and households. Its favoured partner for wind energy is listed as being the US-based Bergey Wind Company. In total, it has more than seventy installations of wind, solar and diesel hybrid systems. It has also installed two wind–solar hybrid solutions for the International Committee of the Red Cross for water desalination plants in Kizingitini and Mtangawanda Islands at Lamu, on the Kenyan coast.

Socabelec East Africa Ltd.[10] is an importer and distributor of wind-power plants and photovoltaic systems and specializes in turnkey power solutions offering various types of hybrid system. Regarding wind energy, it assists customers in everything from wind measurement to project implementation. Its solutions cover both stand-alone systems and grid-connected projects from 300 W up to MW-sized projects. It works closely with turbine manufacturers and states that their preferred partner is Vergnet S.A., which offers a 275 kW solution that is easy to assemble, deliver and install.

Nairobi-based **Trusun Ltd.**[11] is engaged in the design, development, sale, installation and maintenance of various renewable energy products and solutions. For wind generators, it offers four different brands or designs with rated capacities ranging from 200 watts to 2.4 kW. Further specifications of their turbines are listed in great detail on their website.

Sun Power Technologies Limited,[12] based in Sri Lanka, is mainly engaged in the solar energy industry in Kenya, where it is registered as an importer and exporter of various energy technology products, among them small wind-energy systems. It has revealed plans to broaden its portfolio of power plants by investing in the wind-energy sector. The types of services offered include design, installation, construction, engineering, maintenance and repair.

Adept Pacesetters Ltd[13] is registered as a wholesale supplier, exporter and importer of various energy technology products, among them components for both small and large wind energy systems. It describes itself as a consulting engineering firm, but other information is missing.

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9 https://trickleout.net/index.php/directoryofenterprises/kenya/winafrique-technologies-limited

10 https://www.socabelec.co.ke/power-generation-solar-wind-generator/

11 http://www.trusunpower.com/wind-generators/

12 http://www.sunpowertechnologieslk.com/about-us/

13 http://www.adeptpacesetters.com/

Ecosolar[14] was established in Nairobi in 1999, but has activities across all of the Eastern African region. It is described as consultancy that undertakes wind and solar power feasibility studies according to client's power requirements and ahead of turbine installation. Their focus is on diesel power generators, but also through hybrid power systems including wind and solar.

Battery World[15] is based in Nairobi, with branch offices in Tanzania and Uganda. Although it specializes in the provision of batteries, it is also registered as an importer and distributor of wind turbines. Further information is not available.

Chloride Exide[16] likewise specializes in automotive batteries and solar-system installation, but it also lists wind-energy system installation as part of its core business.

7 Estimating Wind Potential at Mini-Grid Sites

The aim of this chapter is to provide an assessment of the proportion of mini-grid sites in Kenya that may be suitable for the integration of small wind turbines, based on an estimate of the wind resource in the immediate area surrounding a mini-grid.

It should be emphasised that this estimate is not based on wind measurements at each site and is therefore hedged with a degree of uncertainty. However, the analysis is based on the very latest scientific wind-resource data from the Global Wind Atlas and as such represents a very appropriate study when looking at a number of geographically dispersed sites throughout the country.

7.1 Methodology for the Assessment of Wind Resources

The basis for estimating wind potential is two sets of data: a) wind resource information from the Global Wind Atlas; and b) mini-grid site locations and mini-grid electrical capacities. The methodology involved in using these two data sets is described in the two sections below.

7.1.1 Extracting Information on Wind Resources from the Global Wind Atlas

The Global Wind Atlas uses large-scale wind-climate data and mesoscale modelling to obtain a set of generalized wind-climate data that cover the globe at a grid spacing of 9 km. These data are then used with microscale modelling techniques, which, together with topographical and land roughness data, produce a series of local wind climates for every 1 km of the globe at heights of 50, 100 and 200 m. More detailed information on these methods can be found on the Global Wind Atlas website (https://globalwindatlas.info/).

[14] https://dk.linkedin.com/company/ecosolar-options-ltd

[15] http://batteryworld.co.ke/wind-energy-2/

[16] https://www.chlorideexide.com/who-we-are/our-profile/

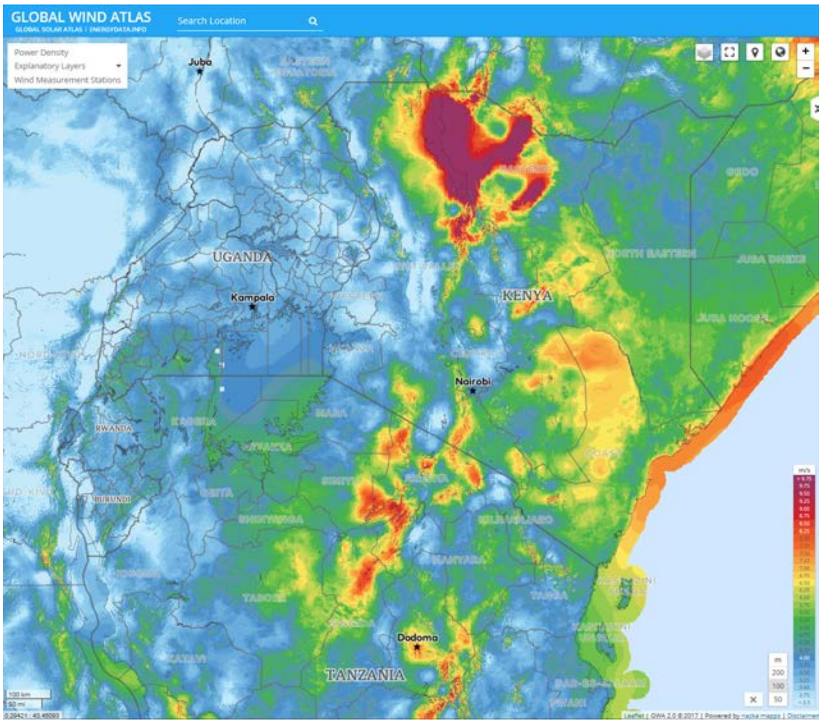

Figure 1. Screen shot from the Global Wind Atlas web browser interface

The Kenya MiniWind project has put together an analysis tool that can help analyse the wind climate data so that it can be related to specific mini-grid sites. The analysis is carried out within a radius of 2.5 km around each mini-grid site location. The reason for taking an area rather than an exact location is three-fold. 1) Production from a small wind turbine is very sensitive to location. It should therefore be located in the optimum position within a reasonable distance of the mini-grid and not necessarily at the exact mini-grid location. 2) It is unlikely that the position of the local wind climate data and the mini-grid location will coincide. 3) The wind climate and topographical data are hedged with a degree of uncertainty that is reduced if more locations are included in the analysis.

For each circle's area around a specific mini-grid location, the Global Wind Atlas data within the area are extrapolated to a height of 20 m above ground so that it is more representative of the resource a small wind turbine would experience. These are then analysed, and the wind speed of the top 10% of the locations with the highest wind speeds are collected and averaged.

Thus, the wind resource information that is extracted is the average of the top 10% annual mean wind speeds from within the 2.5 km radius.

7.1.2 Mini-Grid Site Locations and Mini-Grid Electrical Capacities

The locations for the mini-grid sites are taken from the mini-grid site information, as listed in Tables 1 to 4 of Chapter 3 and Annex 1 of this report. All the sites have been analysed, but only those with an electrical capacity of 150kW or less are presented in the results here. This is to ensure the project's demonstration turbine has a reasonable power-to-capacity ratio to the mini-grid's capacity, given that the envisaged turbine will have a rated capacity of between 5 and 20kW.

The results are presented in terms of four categories of mini-grids, as shown in Table 8:

Table 8. Categories of mini-grids presented in the results

Category	Table	No. of sites
All sites under 150kW	1 to 4	155
K-OSAP sites (<150kW)	Annex 1	89
REA sites (<150kW)	1	25
All other sites (<150kW)	2, 3 and 4	41

In all we have identified 230 sites that are in operation, under construction or at an advanced planning stage. Of those, we have geographical coordinates for 184 sites, of which 155 sites are under 150kW and 29 sites over 150kW. The geographical positions of all 154 sites are shown in Figure 2. It should be noted that this collection of sites does not include the potential 450 trading centres referred to in section 3.1, for which we lack names and coordinates.

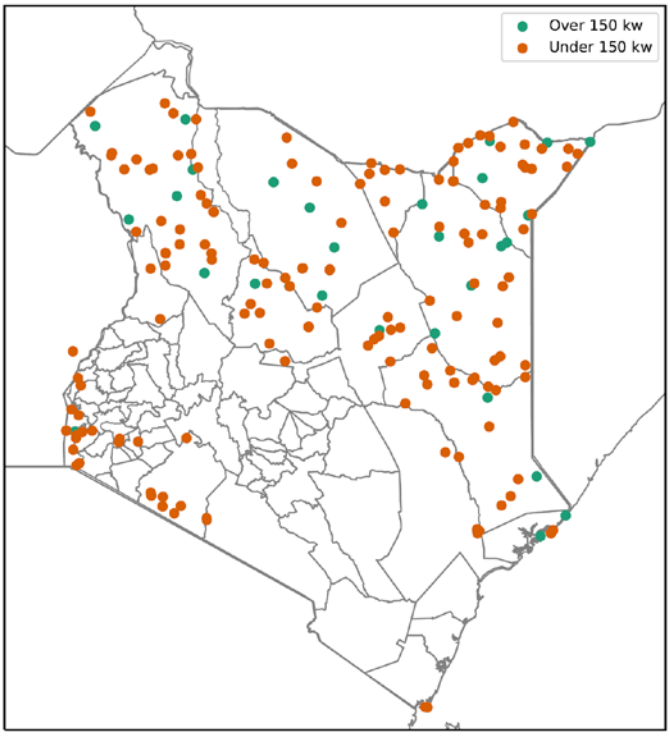

Figure 2. Location of all sites both under and over 150kW

7.2 Classification of Mini-Grids According to Wind Potential

The following maps give the locations of the mini-grid sites in the categories indicated in Table 8 according to the wind potential found in the analysis. An annual average wind speed of 4m/s or above has been chosen as the wind speed indicating whether or not a site has a feasible potential or not. This, of course, is a very coarse delineator because feasibility depends on a huge range of other factors, including specific wind turbine performance, exact siting, mini-grid system design, consumption pattern, economic context, and institutional and community factors, to name just a few. An outline of how the Kenya MiniWind project intends to make a more justifiable feasibility analysis that includes the value of wind energy produced and not just the amount is provided in section 7.4.

It should be noted that the following maps all give indications of the wind potential in m/s, with the numerical value representing the ***average of the top 10% mean annual wind speeds.***

All sites under 150kW

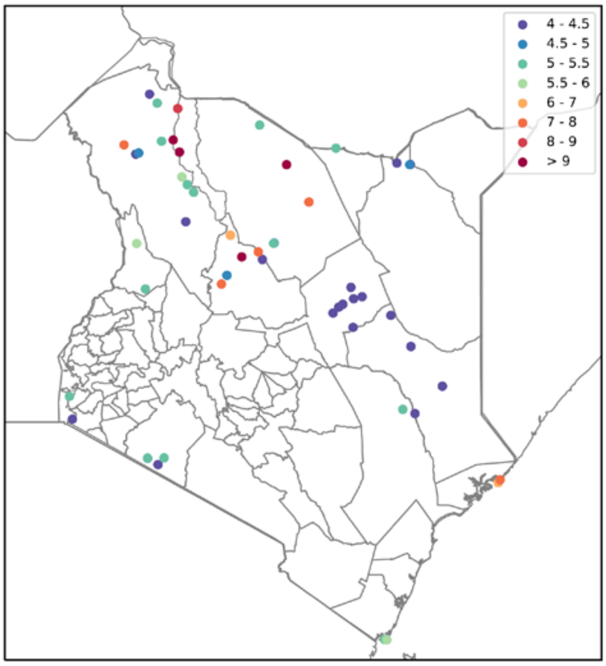

Figure 3. Sites with a wind speed above 4m/s

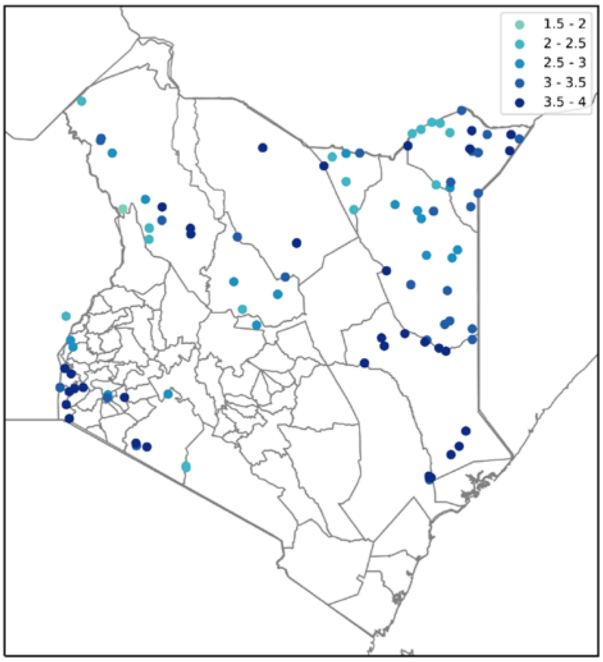

Figure 4. Sites with a wind speed under 4m/s

Summary: of 155 sites, 53 have a wind potential over 4 m/s.

7.2.1 K-OSAP (Kenya Off-Grid Solar Access Project) sites < 150kW

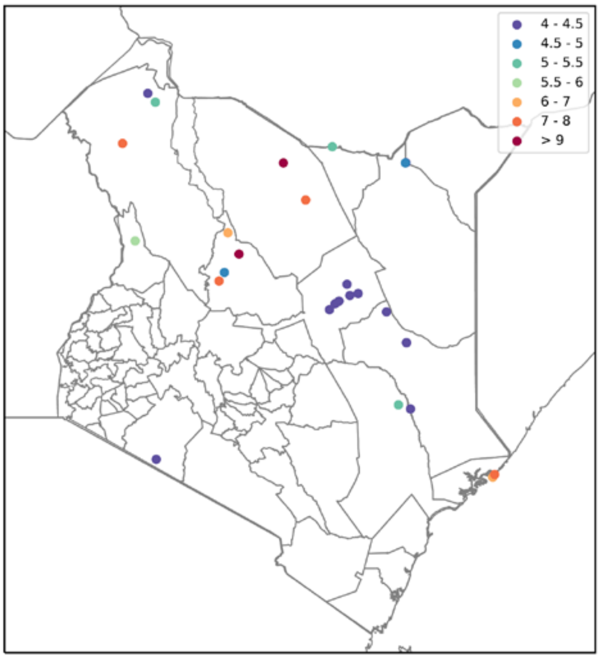

Figure 5. Sites with a wind speed above 4m/s

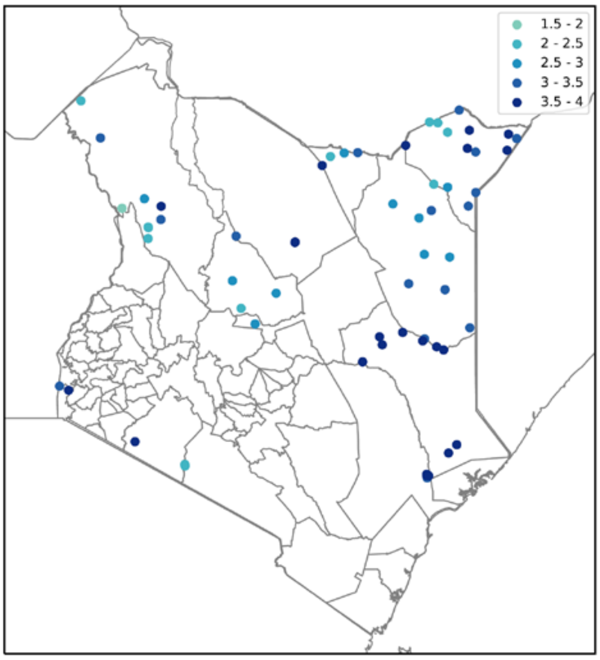

Figure 6. Sites with a wind speed under 4m/s

Summary: of 89 sites, 27 have a wind potential over 4 m/s.

7.2.2 REA (Rural Electrification Authority) < 150kW

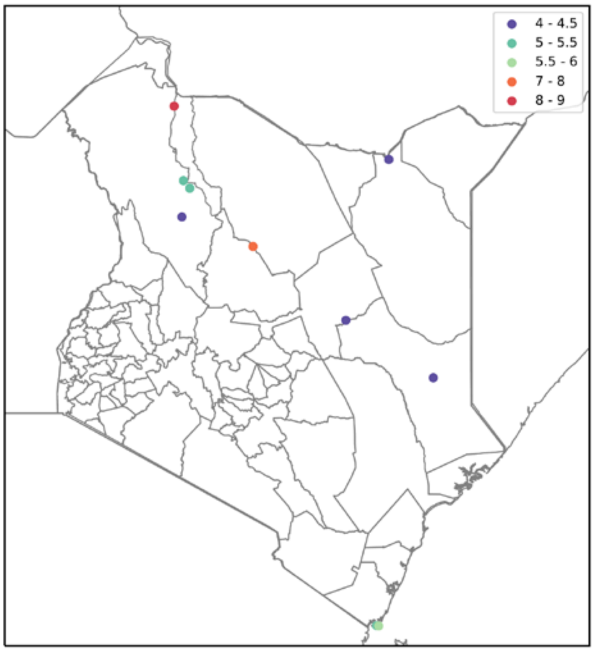

Figure 7. Sites with a wind speed above 4m/s

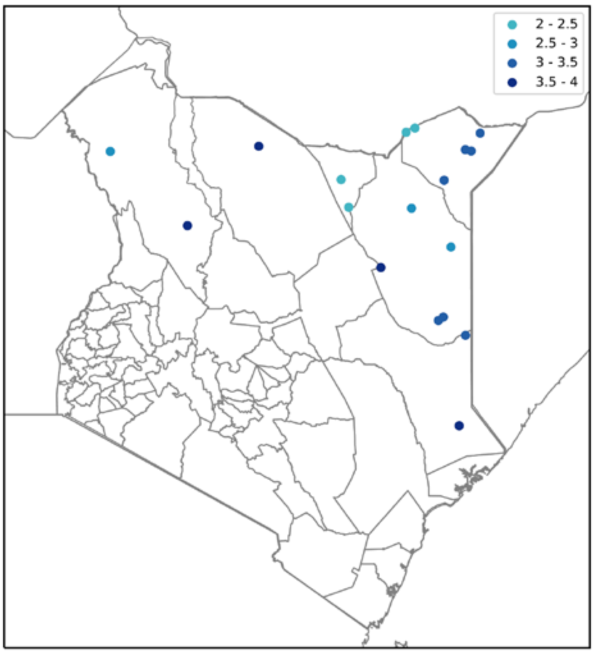

Figure 8. Sites with a wind speed under 4m/s

Summary: of 25 sites, 8 have a wind potential over 4 m/s.

7.2.3 All Other Sites < 150kW

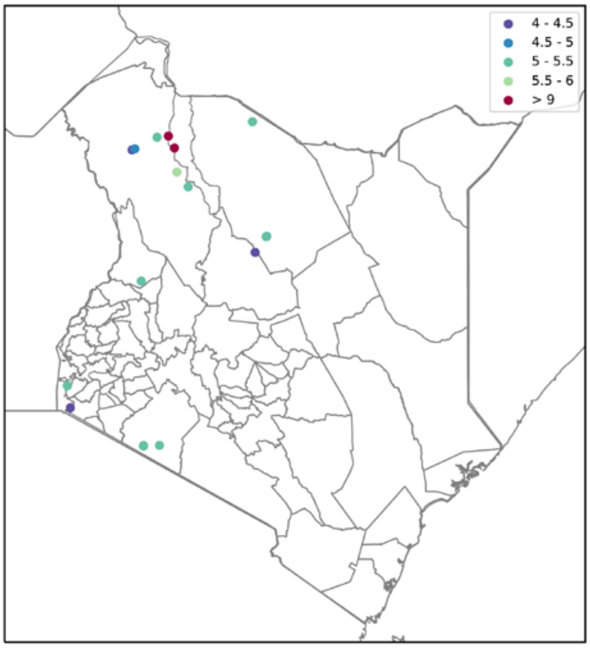

Figure 9. Sites with a wind speed above 4m/s

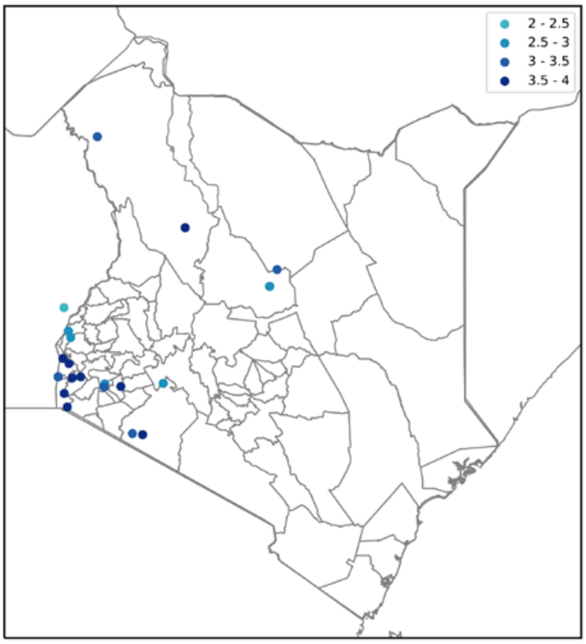

Figure 10. Sites with a wind speed under 4m/s

Summary: of 41sites, 18 have a wind potential over 4 m/s.

7.3 Estimate of Proportion of Potentially Suitable Mini-Grids

Table 9 summarizes the results of the analysis, giving an estimate of the proportion of sites with a wind speed above 4 m/s:

Table 9. Summary of results of analysis

Category	No. of sites	>4m/s	Proportion
K-OSAP sites (<150kW)	89	27	32%
REA sites (<150kW)	25	8	32%
All other sites (<150kW)	41	18	44%
All sites under 150kW	**155**	**53**	**34%**

Thus, from the data set of mini-grids available, it can then be estimated that approximately 53 of the 155 sites (34%) would potentially be suitable for the integration of wind power when considering the wind resource alone.

Table 10 shows the number of sites per wind resource category. It shows that 25 sites are in the range of between 4 and 5 m/s and 28 sites in the range above 5 m/s

Table 10. Number of sites per wind resource category: m/s at 20m height

Wind speed range (m/s)	K-OSAP sites (<150kW)	REA sites (<150kW)	All other sites (<150kW)	All sites under 150kW
4.0 - 4.5	3	4	3	**20**
4.5 - 5.0	3	0	3	**5**
5.0 - 5.5	8	2	8	**13**
5.5 - 6.0	2	0	2	**3**
6.0 - 6.5	0	0	0	**1**
6.5 - 7.0	0	0	0	**1**
7.0 - 7.5	0	1	0	**2**
7.5 - 8.0	0	0	0	**3**
8.0 - 8.5	0	1	0	**1**
8.5 - 9.0				**0**
>9.0	2	0	2	**4**
Total	**27**	**8**	**18**	**53**

7.4 Further Investigation of Feasibility of Wind Power

As part of the Kenya Miniwind Activity 2.1 (Feasibility Studies), a more detailed assessment will be made of the feasibility of the integration of wind power by carrying out preliminary feasibility studies on five case-study sites. These studies will include an assessment of the wind resource but will also cover the range of other aspects necessary when considering introducing a wind turbine into a community with an existing mini-grid.

In combination with this, Activities 4.2 (Demonstration of integration) and 4.6 (Performance of hybrid mini-grid operation) will investigate the **value** of the wind energy produced, rather than the straightforward price of each kWh generated. Much of the economic feasibility of integrating wind power into a mini-grid will depend on the correlations between the temporal profile of wind power production, solar power production and consumer consumption.

7.4.1 Outline of Methodology for Investigating the Value of Wind Power

Conventional mini-grids based on solar PV for generation require a certain amount of battery storage capacity first, to handle fluctuating loads, and second, to be able to provide consumers with energy when the sun is no longer shining. It is frequently during the hours of darkness that much of the load on such mini-grids is present, as the power they generate is used for electric lighting.

The drawback of battery storage (most commonly still using lead-acid technology, as is well known) is that it is costly to purchase and will need regular replacement throughout the life of the mini-grid. However, if a community that is served by an existing mini-grid requires more electrical energy ,then currently there is little choice but to expand the solar PV capacity and, along with it, the battery storage capacity, thus incurring extra costs.

If wind energy is now added by integrating a wind turbine into the mini-grid system, then the value of the energy produced will depend on the daily profile of the wind resource. If the energy produced from wind has a similar profile to that from solar PV, then the competitiveness of the wind energy will be purely on the basis of the cost of energy produced because a similar amount of battery storage will still need to be added.

However, if the wind blows frequently during the hours of dusk and during the night, which is a common phenomenon, then this project believes it can be introduced into the system *without* having to expand the battery capacity. This represents a significant saving in capital expenditure and running expenses and thus an increase in the **value** of wind energy.

To assess the economic benefits of integrating wind power versus adding solar power, this project will carry out a number of simulations of mini-grid scenarios, as outlined above. These will, in the first instance, use generic data, but the simulations will be refined as data is collected from the demonstration turbine and its associated mini-grid.

8 Summary and Conclusion

The Government of Kenya assigns importance to providing access to modern energy for all of its citizens and aims at achieving universal access by 2020 through increased use of renewable energy technologies in the form of mini-grids, whether implemented through commercially driven projects or public-private partnerships. However, private companies are facing challenges in obtaining permits to operate mini-grids and will also need to look for ways of either receiving subsidies or reducing the tariffs they are charging, as these exceed the national grid tariff.

There are currently around fifty public mini-grids either in operation or being developed, while a similar number of private mini-grids have also been identified. A further 121 sites are to be developed with funding from the World Bank, and up to 450 development centres "below the radar" are planned for electrification through renewable energy-based mini-grids over the coming years. Out of 207 mini-grids constructed or planned to be implemented in 2018, we can only estimate wind potential for the 154 sites for which we have coordinates. Of these, 125 sites are below 150 kW, of which 44 (36 %) have a wind potential above 4 m/s at 20 m above ground level.

There is also a potential market for small wind turbines to be connected to grids in sparsely populated areas. This market has not been assessed in this report, but it will be strongly dependent on the future implementation of net-metering schemes, simple and non-bureaucratic agreements with KPLC, and options for mobilizing investments from people or companies living close to the potential sites.

The Kenyan sector for small-scale wind turbines has currently only been developed to a limited extent. Local turbines are relatively simple in their design and are not suitable for integration into mini-grids. Companies offering imported turbines are better positioned for this purpose.

8.1 Policy

The provision of basic needs such as access to electricity forms an integral part of the Government of Kenya's strategy to accelerate economic growth and increase productivity throughout the country. This includes the implementation of rural electrification, where after thirty years of limited progress, the Rural Electrification Agency (REA) was established in 2006 with a mandate to achieve universal access to electricity in rural areas by 2020 (the rural electrification rate in December 2012 was recorded at 26%). REA's first Strategic Plan (2008/09-2012/13) emphasized the connection of public facilities, while the current Strategic Plan has a greater emphasis on households and the use of renewable energy sources, especially with regard to off-grid areas. This is reflected in the budgetary provision of renewable energy, which has increased from 1% in previous Strategic Plans to 50% in the current plan. As such, part of the Strategic Plan is to develop and promote renewable energy generation through mini-grids while also promoting public-private partnerships for implementation. In terms of the policy framework for mini-grids, the Rural Electrification Master Plan update study (REMP) was announced in 2009 to update the national rural electrification strategy for the period 2008-2018.

In compliance with the provisions of the Constitution of Kenya 2010, the Ministry of Energy has prepared a new Energy Policy and Bill which proposes to enhance REA's mandate in the promotion and development of renewable energy. The documents were tabled in Parliament in April 2015 and are awaiting consideration and approval in the House.

In 2016, development of the Kenya National Electrification Strategy (KNES) was initiated through the Kenya Electricity Modernization Project (KEMP), which is funded by the World Bank and managed by MoE. A first draft of the Kenya National Electrification Strategy was released to government in January 2017 (NRECA 2017). The strategy has not yet been published.

8.2 Implementation and Regulation

REA typically develops public mini-grids and subsequently hands over their operation and maintenance to Kenya Power, which also operates and maintains the national grid. For privately operated mini-grids the procedures for obtaining a permit are lengthy and have high transaction costs, with the result that many private mini-grids are currently operating without a permit. The Energy Act requires mini-grids with a capacity of less than 3 MW to obtain a permit that is granted after an investigation of the tariff to be charged and the health and safety aspects as regards users. Once a permit has been granted to a firm, other firms (including the utility and REA) cannot compete in the same area. However, there is no established approach for firms wanting to establish multiple sites, and there is also a lack of provisions for connecting mini-grids to the national grid when relevant. To some extent, county governments will play a role in planning the expansion of rural electrification by working with REA to develop mini-grids, with private companies subsequently being contracted for operations and maintenance, as seen in the case of Narok, for example.

8.3 Current and Planned Mini-Grids

The available lists of current and planned mini-grids in Kenya are indicative of the activity in the market. In terms of current public mini-grids, there are 27 larger sites, mostly relying on diesel, being operated by Kenya Power, which offers a tariff similar to that of the rest of the country thanks to cross-subsidization. Ten of these sites have been hybridized with solar and two with wind, while a further thirteen mini-grids will be covered in an upcoming round of hybridization. At the time of writing in 2018, there are 26 additional mini-grids due to be developed by REA, all of them PV-based with diesel and battery back-up.

For private mini-grids, there are currently 22 sites that are run based on a model of the private ownership of both generation and distribution assets and with cost-reflective tariffs, which are therefore higher than the national grid tariff. The UK's Department for International Development (DfID) has established a Green Mini-Grid Facility as an initiative to subsidize the capital costs of green private mini-grids to help lower the tariff. Although there is scope for lowering the tariff charged by solar-based private mini-grids – for instance, through the integration of wind turbines – the tariffs charged by these mini-grids are still higher than those for public mini-grids. A further eighteen private mini-grids are currently being developed. Private companies that are developing mini-grids in Kenya include PowerGen, Powerhive. Renewvia Energy and RVE.SOL.

Further, eleven community-based mini-grids are being developed by NGOs, charities and universities, most often being heavily subsidized. Recently the UK-based charity Renewable World has implemented a portfolio of projects in Kenya.

In addition to the strictly public and private-based model, there is a public–private partnership model in which a private developer invests in the generation assets while the government funds the distribution assets. KPLC subsequently purchases the electricity produced and distributes it to consumers at a price equivalent to that of the grid tariff, meaning that KPLC is effectively cross-subsidizing the beneficiaries of these mini-grids. It is planned to implement 121 solar mini-grids according to this model, supported by the World Bank in the so-called K-OSAP plan.

Finally, 450 smaller market centres are due to be electrified through solar based mini-grids in the coming years, most likely by private companies partly subsidized by the Green Mini-Grid Facility. They are so far under the radar, and the project not been able to obtain more detailed information about the size and position of these sites.

8.4 Mini-Grids with Wind Potential above 4 m/s

For the purposes of assessing the wind resources in the vicinity of relevant mini-grid sites, it was decided to focus mainly on sites with a capacity below 150 kW because this is the appropriate capacity range for a turbine of the size of 5 to 20 kW that is to be developed for this project. Furthermore, an annual average wind speed of 4 m/s was set as the limit above which sites would be included for having a feasible potential. Of the 155 sites with a capacity below 150 kW for which we have coordinates, 53 have a wind potential above 4 m/s. 27 of these sites are K-OSAP sites (27 out of 89 with coordinates), while REA and other sites account for 8 and 18 sites respectively.

Table 11. Number of sites above 4 m/s

Category	No. of sites	>4m/s	Proportion
K-OSAP sites (<150kW)	89	27	32%
REA sites (<150kW)	25	8	32%
All other sites (<150kW)	41	18	44%
All sites under 150kW	**155**	**53**	**34%**

As part of the Kenya Miniwind project, feasibility studies will be carried out on five case sites to arrive at a more detailed assessment of the feasibility of integrating wind power into mini-grids. Moreover, the economic feasibility of doing so will depend on the correlation between the temporal profile of wind power production, solar power production and consumer consumption.

8.5 Import, Production and Installation of Wind Turbines

While the use of small-scale wind turbines in mini-grids has been very limited to date, their use for stand-alone power generation or water pumping has been practiced in Kenya since the early 1980s. The sector has mainly been dominated by established importers of energy systems who, during the late 1990s, added small-scale wind turbines to their portfolios. The number of local manufacturers is limited, with two main players (Craftskills and Kijito) operating in past decades. However, the locally produced turbines are relatively simple in their design and are manufactured according to various local contexts and from a range of locally available materials. The turbines therefore do not require advanced engineering knowledge, and their manufacture is characterized rather by local craftsmen and blacksmiths tinkering with designs and materials. The turbines typically boast a capacity of between 150 W and 3 kW, with around 120-150 of this kind having been installed as of 2012. The nature of most commercial solar-based mini-grids means that locally manufactured turbines are currently not well-positioned as an option for the hybridization of these mini-grids. In addition to the locally manufactured turbines, there are a number of firms importing turbines from abroad. These turbines, although more expensive, are more suitable for integration into solar-based mini-grids, as they typically have a capacity in the range of 1-5 kW. Increasingly local companies are offering imported turbines from China, although two American companies (Southwest Wind Power and Bergey Wind Power) have been identified as the preferred partners of some local importers. Among the most relevant local companies related to small-scale wind turbines are East African Wind Energy Ltd, Kijito Windpower, Craftskills East Africa Limited, Winafrique Technologies Limited, Socabelec East Africa Ltd. and Trusun Ltd.

9 References

The information contained in this report is based on various documents and materials that have been reviewed in its preparation. While these documents provide the underlying foundation for the report, only documents that have been explicitly referenced throughout the report are listed in this section.

An overview of the vast amount of literature on the topic of mini-grids in East Africa that has served to inform the writing of the report but has not been explicitly referenced in it is given in Annex 2.

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Annex 1. Details of Mini-Grids

(a) Operational public mini grids

No.	Site Name	County	Coordinates	Commissioning Date	Owned By	Operated By	Diesel Capacity (kW)	Solar Capacity (kWp)	Wind Capacity (kW)	Wind Data at 40m (m/s)	Batteries Capacity (AH)	Number of Connections (June 2016)	Number of HH (2009)	Annual average wind speed (m/s)*
1	Marsabit	Marsabit	2.332077, 37.985681	1977	REA	KPLC	2900	0	500	N/A	0	8,200	N/A	9.3
2	Wajir	Wajir	1.7537, 40.05791	1982	REA	KPLC	4200	0	0	5.15	0	12,055	N/A	2.9
3	Lodwar	Turkana	3.11245, 35.60634	1976	REA	KPLC	3425	60	0	N/A	0	9,598	N/A	3.8
4	Mandera	Mandera	3.93699, 41.8555	1979	REA	KPLC	3130	330	0	N/A	0	8,000	N/A	2.8
5	Habaswein	Wajir	1.02566, 39.50782	2007	REA	KPLC	1160	30	50	6.33	88,200	1,180	N/A	4.1
6	Merti	Isiolo	1.07359, 38.66949	2007	REA	KPLC	250	10	0	5.95	0	1,485	N/A	4.1
7	Elwak	Mandera	2.82074, 40.91838	2009	REA	KPLC	740	50	0	N/A	0	1,700	N/A	3.2
8	Baragoi	Samburu	1.78138, 36.78926	2009	REA	KPLC	240	0	0	5.46	0	473	N/A	4.4
9	Mfangano	Homa Bay	-0.46933, 34.06499	2009	REA	KPLC	650	10	0	3.78	0	3,000	N/A	3.4
10	Lokichoggio	Turkana	4.17813, 34.36896	2010	REA	KPLC	1050	0	0	4.89	0	350	N/A	2.8
11	Eldas	Wajir	2.49928, 39.56992	2013	REA	KPLC	184	30	0	N/A	72,960	342	N/A	3.0
12	Takaba	Mandera	3.38632, 40.22674	2013	REA	KPLC	320	50	0	4.45	72,000	500	N/A	3.3
13	Rhamu	Mandera	3.92445, 41.20791	2013	REA	KPLC	520	50	0	4.37	0	400	N/A	3.0
14	Laisamis	Marsabit	1.59937, 37.80263	2016	REA	KPLC	264	80	0	5.02	27,816	160	N/A	4.8
15	North Horr	Marsabit	3.32412, 37.06738	2016	REA	KPLC	184	0	0	7.54	0	160	N/A	6.3
16	Lokori	Turkana	1.94337, 36.02279	2016	REA	KPLC	184	0	0	N/A	0	150	N/A	2.9
17	Daadab	Garissa	0.04672, 40.30662	2016	REA	KPLC	784	0	0	5.47	0	4,800	N/A	3.7
18	Faza	Lamu	-2.0605, 41.10662	2017	REA	KPLC	1370	0	0	5.66	0	2,010	N/A	5.1
19	Kiunga	Lamu	-1.74743, 41.48614	2017	REA	KPLC	260	0	0	N/A	0	350	N/A	7.7
20	Banissa	Mandera	3.95151, 40.33827	2018	REA	KPLC	260	0	0	5.41	0	Compl./not op.	N/A	2.4
21	Hulugho	Garissa	-1.15325, 41.04738	2018	REA	KPLC	240	0	0	N/A	0	Compl./not op.	N/A	3.7
22	Lokiriama	Turkana	2.75869, 34.87764	2018	REA	KPLC	800	0	0	N/A	0	Compl./not op.	N/A	2.9
23	Kamorliban	Mandera	2.407572, 40596868	2018	REA	KPLC	402	0	0	N/A	0	Compl./not op.	N/A	2.9
24	Kotulo	Wajir	2.35161, 40.51105	2018	REA	KPLC	360	0	0	N/A	0	Compl./not op.	N/A	2.1
25	Kholondile	Wajir	2.99054, 39.31657	2018	REA	KPLC	184	0	0	N/A	0	Compl./not op.	N/A	6.8
26	Lokitaung	Turkana	4.2786, 35.73514	2018	REA	KPLC	184	0	0	5.54	0	34	N/A	5.6
27	Biyamadhow	Wajir	0.615302, 40.412136	2018	REA	KPLC	50	60	0	N/A	78,600	Compl./not op.	200	3.1

(Source: Kenya Power – Eng. Henry Kapsowe, Chief Engineer, Off-grid Power Stations for mini grid data and Wind Energy Data Analysis Programme, Eng. Kihara Mungai of MoE)

* Annual average wind speed = the average of the top 10% annual mean wind speeds from within a 2.5km radius circle of the mini-grid location

(b) Private mini grids														
No.	**Site Name**	**County**	**Coordinates**	**Commissioing Date**	**Owned By**	**Operated By**	**Diesel Capacity (kW)**	**Solar Capacity (kWp)**	**Wind Capacity (kW)**	**Wind Data at 40m (m/s)**	**Batteries Capacity (AH)**	**Number of Connections**	**Number of HH (2009)**	**Annual average wind speed (m/s)***
1	Kirwa C	Kisii	Not available (N/A)	N/A	Powerhive	Powerhive	N/A	10	0	N/A	N/A	N/A	N/A	N/A
2	Mtangamano	Kisii	N/A	N/A	Powerhive	Powerhive	N/A	21	0	N/A	N/A	N/A	N/A	N/A
3	Bogeka	Kisii	-0.63, 34.72722	N/A	Powerhive	Powerhive	N/A	10	0	N/A	N/A	N/A	N/A	3.0
4	Mokomoni	Kisii	-0.62138, 35.01722	N/A	Powerhive	Powerhive	N/A	1.5	0	N/A	N/A	N/A	N/A	3.6
5	Nyamondo	Kisii	-0.57805, 34.73916	N/A	Powerhive	Powerhive	N/A	10.5	0	N/A	N/A	N/A	N/A	2.8
6	Barane	Kisii	N/A	N/A	Powerhive	Powerhive	N/A	47.25	0	N/A	N/A	N/A	N/A	N/A
7	Talek	Narok	-1.44383, 35.21805	2015	Narok C. Gov.	Powergen	6.8	40	0	N/A	108,000	200	300	3.5
8	Sindonge	Busia	0.3455801, 34.1070389	2011	RVE.SOL	RVE.SOL	0	7	0	N/A	26,040	40	250	2.5
9	Remba	Homa Bay	-0.45473, 33.93195	2017	Dream EP	Disconnected	0	15	0	N/A	3,000	N/A	N/A	3.3
10	Ngoswani	West Pokot	1.243551, 35.352885	2015	Dream EP	Dream EP	0	3	0	N/A	300	N/A	N/A	5.5
11	Oloilamutia 1	Narok	-1.61001, 35.39057	2014	Powergen	Powergen	0	2.25	0	N/A	440	N/A	N/A	5.0
12	Oloilamutia 2	Narok	-1.6051, 35.3892	2014	Powergen	Powergen	0	2.25	0	N/A	440	N/A	N/A	5.2
13	Naikara	Narok	-1.60109, 35.66604	2014	Powergen	Powergen	0	4.5	0	N/A	400	N/A	N/A	5.3
14	Nkoilale	Narok	-1.46216, 35.3946	2014	Powergen	Powergen	0	1.5	0	N/A	220	N/A	N/A	3.7
15	Olposmoru	Nakuru	-0.56771, 35.75217	2015	Powergen	Powergen	0	6	0	N/A	660	N/A	N/A	2.7
16	Sereolipi 1	Samburu	1.1219, 37.59656	2015	Access Energy	Unknown	0	1.5	0	N/A	220	N/A	N/A	2.7
17	Sereolipi 2	Samburu	1.12551, 37.59753	2015	Access Energy	Unknown	0	1.5	0	N/A	220	N/A	N/A	2.7
18	Gambela 1	N/A	N/A	2015	Access Energy	Unknown	0	1.5	0	N/A	220	N/A	N/A	N/A
19	Gambela 2	N/A	N/A	2015	Access Energy	Unknown	0	1.5	0	N/A	220	N/A	N/A	N/A
20	Merille	Marsabit	1.41786, 37.72524	2014	Access Energy	Unknown	0	1.5	0	N/A	N/A	N/A	N/A	3.3
21	Ndeda	Siaya	-0.221772, 34.1172472	2018	Renewvia Energy	Renewvia Energy	0	9.75	0	N/A	1000/48kWh	N/A	N/A	3.8
22	Ringiti Island	Homa Bay	-0.4557, 33.9329083	2018	Renewvia Energy	Renewvia Energy	0	20.475	0	N/A	2000/96 KWh	N/A	N/A	3.3
(Source: Nickson Bukachi, ERC; Jackson Mutonga, GIZ; www.rvesol.com; Brian Sikuku, Renewvia)														

* Annual average wind speed = the average of the top 10% annual mean wind speeds from within a 2.5km radius circle of the mini-grid location

(c) Community-based mini-grids													
No.	**Site Name**	**County**	**Coordinates**	**Commissioing Date**	**Owned By**	**Operated By**	**Diesel Capacity (kW)**	**Solar Capacity (kWp)**	**Wind Capacity (kW)**	**Wind Data at 40m (m/s)**	**Batteries Capacity (AH)**	**Number of Connections**	**Number of HH (2009)**
1	Ragwe beach	Homa Bay	-0.5666606, 34.081285	N/A	Renewable World	Renewable World	0	5	0	N/A	4800	N/A	N/A
2	Ng'ore Beach	Migpori	-0.981960, 34.089235	N/A	Renewable World	Renewable World	0	1.5	0	N/A	800	N/A	N/A
3	Mirunda	Homa Bay	-0.456111, 34.322500	N/A	Renewable World	Renewable World	0	3.5	0	N/A	4000	N/A	N/A
4	Sika, Magetta Island	Siaya	-0.133621, 34.011226	N/A	Renewable World	Renewable World	0	3	0	N/A	3200	N/A	N/A
5	Kiwa Island	Homa Bay	-0.744700, 34.036517	N/A	Renewable World	Renewable World	0	5	0	N/A	4800	N/A	N/A
6	Got Kachola Beach	Migori	-0.949011, 34.131314	N/A	Renewable World	Renewable World	0	2	0	N/A	1600	N/A	N/A
7	Tabla Beach	Homa Bay	-0.474867, 34.172992	N/A	Renewable World	Renewable World	0	1.5	0	N/A	400	N/A	N/A
8	Kitonyoni	Makueni	N/A	2012	Uni. S. Hampton	Uni. S. Hampton	37	13.5	0	N/A	N/A	N/A	N/A
9	Oloika	Kajiado	N/A	N/A	Uni. S. Hampton	Uni. S. Hampton	N/A	13.5	0	N/A	38.4 kWh	N/A	N/A
10	Shompole	Kajiado	N/A	N/A	Uni. S. Hampton	Uni. S. Hampton	N/A	8.4	0	N/A	38.4 kWh	N/A	N/A
11	Olosho-Oibor	Ngong	N/A	2009	UNIDO	UNIDO	10	7	3	N/A	N/A	N/A	N/A
(Source: Geoffrey Mburu, Renewable World; Gollwitzer 2017 ; www.energyfordevelopment.net)													
* Annual average wind speed = the average of the top 10% annual mean wind speeds from within a 2.5km radius circle of the mini-grid location													

(d) REA's mini grids currently under construction

No.	Site Name	County	Coordinates	Planned Commissioing Date	Owned By	Operated By	Diesel Capacity (kW)	Solar Capacity (kWp)	Wind Capacity (kW)	Wind Data at 40m (m/s)	Batteries Capacity (AH)	Number of Connections (June 2016)	Number of HH (2009)
1	Maikona	Marsabit	2.93755, 37.61426	2018	REA	KPLC	700	0	0	7.02	0	New	N/A
2	Sangailu	Garissa	-1.194539, 40.767876	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
3	Liboi	Garissa	0.358807, 40.875544	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
4	Eldera	Isiolo	0.596416, 38.832979	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
5	Garsweino	Garissa	-0.39344, 40.32866*	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
6	Kiliwehiri	Mandera	3.918747, 40.011542	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
7	Burduras	Mandera	3.84635, 39.86303	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
8	Arabia	Mandera	3.831698, 41.125642	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
9	Gari	Mandera	3.52627, 40.9723	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
10	Shimbir Fatuma	Mandera	3.024592, 40.510366	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
11	Ashbito	Mandera	3.54768, 40.87343	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
12	Ambalo	Marsabit	3.034535, 38.751159	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
13	Balesa	Marsabit	3.606882, 37.345746	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
14	Illaut	Marsabit	1.867324, 37.245455	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
15	Kerio	Turkana	3.000751, 36.054637	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
16	Napelilim	Turkana	2.87052, 36.16304	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
17	Lowarengak	Turkana	4.279827, 35.895929	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
18	Letea	Turkana	3.518833, 34.810382	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
19	Lopeduru	Turkana	2.243834, 36.127478	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
20	Kangangipur	Turkana	2.376815, 36.029339	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
21	Sarman	Wajir	2.542398, 39.953998	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
22	Riba	Wajir	1.877106, 40.627447	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
23	Gurar	Wajir	3.364300, 39.567907	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
24	Basir	Wajir	2.558985, 38.880851	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
25	Hadado	Wajir	1.524109, 39.429942	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A
26	Sarif	Wajir	0.674320, 40.496420	2018	REA	KPLC	50	60	Nil	N/A	76,800	Nil	N/A

(Source: James Muriithi, REA)

* Annual average wind speed = the average of the top 10% annual mean wind speeds from within a 2.5km radius circle of the mini-grid location

(e) Private solar mini grids currently under development														
No.	**Site Name**	**County**	**Coordinates**	**Planned Commissioning Date**	**Owned By**	**To be Operated By**	**Diesel Capacity (kVA)**	**Solar Capacity (kWp)**	**Wind Capacity (kW)**	**Wind Data at 40m (m/s)**	**Batteries Capacity (AH)**	**Number of Connections (June 2016)**	**Number of HH**	**Annual average wind speed (m/s)***
1	Naduat	Turkana	3.51359, 35.19332	2018	Nirav Agencies Limited	Nirav Agencies Limited	28	40	0	N/A	2770	Nil	200	4.2
2	Lorupe	Turkana	3.53261, 35.24053	2018			12	15	0	N/A	1800	Nil	160	4.6
3	Kataboi	Turkana	3.75282, 35.82006	2018			18	20	0	N/A	1900	Nil	100	9.1
4	Longech	Turkana	3.54787, 35.92457	2018			30	45	0	N/A	3800	Nil	240	10.0
5	Illeret	Marsabit	N/A	N/A			N/A	25	0	N/A	N/A	Nil	N/A	N/A
6	Dukana	Marsabit	N/A	N/A			N/A	35	0	N/A	N/A	Nil	N/A	N/A
7	Kangatotha	Turkana	3.12922, 35.9658	2018	Strauss Energy Limited	Strauss Energy Limited	8	16	0	N/A	2400	Nil	120	5.6
8	Katilia	Turkana	2.14638, 36.13308	2018			30	40	0	N/A	6000	Nil	200	3.8
9	Nakurio	Turkana	2.87513, 36.16124	2018			16	25	0	N/A	4000	Nil	160	5.4
10	Korr	Marsabit	2.0176, 37.510161	2019	Renewvia Energy	Renewvia Energy	N/A	60	0	N/A	9000/432	Nil	N/A	5.0
11	Ngurunit	Marsabit	1.7406, 37.31396	2019	Renewvia Energy	Renewvia Energy	N/A	27	0	N/A	5000/240	Nil	N/A	4.1
12	Kiwa	Siaya	0.752672, 34.032127	N/A	Renewvia Energy	Renewvia Energy	N/A	11	0	N/A	1000/48	Nil	N/A	2.5
13	Oyamo	Siaya	0.23083 34.1500972	N/A	Renewvia Energy	Renewvia Energy	N/A	10	0	N/A	8000/38.4	Nil	N/A	2.7
14	Kalobeyei Town	Turkana	3.7313545, 35.62416	2019	Renewvia Energy	Renewvia Energy	N/A	20	0	N/A	2000/96	Nil	N/A	5.3
15	Kalobeyei Settl.	Turkana	3.7313685, 34.611278	2019	Renewvia Energy	Renewvia Energy	N/A	60	0	N/A	500/240	Nil	N/A	3.1
16	Kalokol	Turkana	3.5147, 35.84667	2019	GIZ have taken over from KfW		200	370	0	N/A	90,167	Nil	2,300	7.4
17	Ngurunit	Marsabit	1.74269, 37.30618	2019			100	180	0	N/A	47,208	Nil	3,600	4.4
18	Dukana	Marsabit	4.0016, 37.26665	2019			100	140	0	N/A	41,292	Nil	2,200	5.2
(Source: Jackson Mutonga, GIZ; Brian Sikuku, Renewvia Energy)														

(f) K-OSAP Mini-Grid list

SL NO	Cluster Number	County	MiniGrid Name	Potential Consumers	Longitude	Latitude	Annual average wind speed (m/s)*
* Annual average wind speed = the average of the top 10% annual mean wind speeds from within a 2.5km radius circle of the mini-grid location							
1	1	Turkana	Angorangora	134	35.367831	2.733493	2.9
2	1	Turkana	Chepropoi	172	35.430656	2.055926	2.0
3	1	Turkana	Kaaling	157	35.551036	4.371084	5.2
4	1	Turkana	Kairor	151	35.422373	4.521805	4.4
5	1	Wes Pokot	Kasei	106	35.207119	2.009844	5.7
6	1	Turkana	Kalobeyei	124	34.624469	3.767224	3.1
7	1	Turkana	Lobrokut1	155	35.432492	2.251129	2.1
8	1	Turkana	Lobrokut2	402	35.437198	2.241753	2.1
9	1	Turkana	Loichangamata	120	35.651964	2.605567	3.9
10	1	Turkana	Lokariwon	108	34.29525	4.396342	2.3
11	1	Turkana	Lorengipi	112	34.990559	2.571671	1.8
12	1	Turkana	NADUAT TC	233	35.646746	2.37951	3.4
13	1	Turkana	Nakapelikuruk	119	34.995015	3.670545	7.0
14	2	Isiolo	BADANA	107	38.983325	1.113954	4.4
15	2	Isiolo	ERAS HA BORU	370	38.843045	1.079561	4.4
16	2	Isiolo	GARFASA	263	38.59268	0.938773	4.3
17	2	Isiolo	KIPSING	110	37.242224	0.602316	2.8
18	2	Isiolo	Bassa	100			
19	2	Isiolo	Kombolla	80	38.660112	0.985444	4.2
20	2	Isiolo	Malkadaka	161	38.497688	0.839427	4.5
21	2	Isiolo	MALKAGHALA	173	38.796214	1.271735	4.3
22	2	Marsabit	BORI	137	38.978972	3.517837	3.2
23	2	Marsabit	Bubisa	189	38.093904	2.707413	7.6
24	2	Marsabit	Dambala Fachana(West)	142	38.749717	3.511159	2.9
25	2	Marsabit	Liis	165	38.376493	3.299575	3.6
25.1	3	Marsabit	Log-Logo1	261	37.916308	1.988824	4.0
25.2	3	Marsabit	Log-Logo2	125	37.919217	1.99823	3.8
26	2	Marsabit	El bor / Uran	166	38.546386	3.613131	5.0
27	2	Marsabit	Gas/Walda	214	38.516212	3.45281	2.3
28	2	Marsabit	Furore				
29	2	Marsabit	Hurri Hills		37.718766	3.337455	10.1
30	2	Marsabit	South Horr	310	36.91887	2.098097	3.2
31	2	Samburu	Barsaloi	137	36.858431	1.338325	2.6
32	2	Samburu	Lasirikan	145	36.967702	1.785008	10.4
33	2	Samburu	Lodungokwe	121	37.004773	0.869732	2.4
34	2	Samburu	Morijo (Nanyokie)	162	36.628483	1.32649	7.9
35	2	Samburu	Sereolipi	164	37.59902	1.126082	2.8
36	2	Samburu	TUUM	150	36.777899	2.148991	6.1
37	2	Samburu	Marti		36.719408	1.472934	4.5
38	3	Wajir	Burder(West)	107	40.455632	1.186712	3.0
39	3	Wajir	Daaful(South)	336	40.314021	0.214382	3.6
40	3	Wajir	Dadajabula	138	40.87516	0.538354	3.3

41	3	Wajir	Dambas	112	40.017073	2.407254	2.8
42	3	Wajir	Danaba2	117	39.78188	3.337649	4.6
43	3	Wajir	Dif				
44	3	Wajir	Wajir Bor		40.534815	1.742059	3.0
45	3	Wajir	Koton				
46	3	Wajir	Boji Garas				
47	3	Wajir	Kajaja Two East				
48	3	Wajir	Jowhar		40.104224	1.786582	2.6
49	3	Wajir	Dasheeg East				
50	3	Wajir	Malkaguftu	111	39.57398	2.645116	3.0
51	3	Wajir	MANSA TC	113	40.223731	2.532943	3.5
52	3	Wajir	LAGBOGHOL MKT	149	39.840204	1.287589	3.1
53	3	Mandera	Danaba1	186	39.792219	3.339799	4.5
54	3	Mandera	BURMAYO TC	136	40.265679	2.979919	2.5
55	3	Mandera	Dabasiti(West)	151	40.849642	2.608536	3.1
56	3	Mandera	FINICHARO	123	40.501246	2.930335	2.8
57	3	Mandera	Guba	118	40.499582	3.863404	2.3
58	3	Mandera	Hameyi	215	40.193628	4.036619	2.4
59	3	Mandera	Koridzhub	268	41.505879	3.557028	3.7
60	3	Mandera	Birkan	200			
61	3	Mandera	Burashum	80			
62	3	Mandera	Olla	300	40.867746	3.896551	3.7
63	3	Mandera	Githera				
64	3	Mandera	Kabo				
65	3	Mandera	Bambo		40.973551	3.528476	3.0
66	3	Mandera	Golgo				
67	3	Mandera	Guticha		40.834935	3.589565	3.6
68	3	Mandera	Shirshir				
69	3	Mandera	Qalangalesa	175			
70	3	Mandera	Dawdar	130			
71	3	Mandera	Qarsadamu	145			
72	3	Mandera	Katayu	150			
73	3	Mandera	Elgolicha	160	40.975872	2.839131	3.2
74	3	Mandera	Elkhala	142			
75	3	Mandera	Libehia		41.528217	3.830884	3.5
76	3	Mandera	Gumbiso				
77	3	Mandera	Sarohindi				
78	3	Mandera	Omar Jillow		41.6678	3.756079	3.3
79	3	Mandera	Sake		39.789608	3.640643	3.9
80	3	Mandera	Lulis	100	40.33494	4.022539	2.5

80	3	Mandera	Gagaba				
81	3	Mandera	Malkamari	191	40.694833	4.238913	3.1
83	4	Garissa	Baraki	171	39.346104	0.385623	3.9
84	4	Garissa	Dujis	191	39.393462	0.248952	3.5
85	4	Garissa	Garufa	126	39.464429	0.799765	4.0
86	4	Garissa	Goreale	410	39.801037	0.277427	4.2
87	4	Garissa	IJARA TOWN	315	40.515881	-1.593706	3.5
88	4	Garissa	Kulan(West)	108	40.431651	0.161127	3.6
89	4	Garissa	SABULI	210	40.110377	0.349392	3.4
90	4	Garissa	Shantabak	289	39.739617	0.459203	3.6
91	4	Garissa	Dertu		39.802181	0.273783	4.2
92	4	Garissa	Damajaley				
93	4	Garissa	Hamey				
94	4	Garissa	Ali Kune				
95	4	Garissa	Kumahumato		40.077349	0.315179	3.7
96	4	Garissa	Abakaile				
97	4	Garissa	Welhar				
98	4	Garissa	Kokar				
99	4	Garissa	Weldoni				
100	4	Garissa	Kotile		40.180424	-1.982059	3.7
101	4	Garissa	Bodhai				
102	4	Garissa	Gababa		40.162217	-1.547117	
103	4	Garissa	Jalish				
104	4	Garissa	Bodhai				
105	4	Garissa	Handaro		40.654931	-1.451765	3.6
106	4	Lamu	KIWAYU	105	41.263521	-2.01799	7.0
107	4	Lamu	Mkokoni	119	41.296318	-1.970566	7.9
108	4	Lamu	Budhei				
109	4	Lamu	Mangai				
110		Lamu	Ndao Island				
111	4	Tana River	Kitere	166	40.146065	-1.954813	3.6
112	4	Tana River	MBALAMBALA	296	39.060502	-0.041369	3.9
113	4	Tana River	Mnazini	205	40.147957	-1.979581	3.6
114	4	Tana River	Munguvinikinyadu	127	40.153675	-2.017394	3.5
115	4	Tana River	Nanigi East	134	39.869953	-0.85475	4.4
116	4	Tana River	Tana River	152	39.665796	-0.78539	5.5
117	6	Kajiado	KalemmaKalema	233	36.053976	-1.787504	2.4
118	6	Kajiado	nkurumani(North)	181	36.057261	-1.813414	2.3
119	6	Narok	Koiyaki(South)	134	35.209498	-1.399573	3.8
120	6	Narok	Olderkesi(North)	102	35.565367	-1.713295	4.5
120.1	6	Homa Bay	Kibuogi	152	34.086527	-0.525371	3.9
120.2	6	Homa Bay	Ringiti Island	331	33.933375	-0.455674	3.3

Annex 2. Literature List: Mini-Grids in East Africa

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